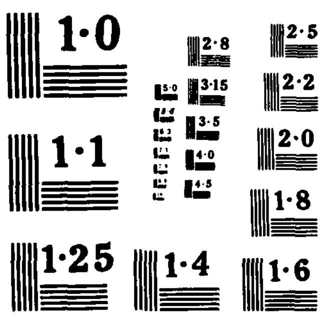
AD-A156 831   AN EVOLVING DIGITAL TELECOMMUNICATIONS INDUSTRY AND ITS   1/2
IMPACT ON THE OPE..(U) NAVAL POSTGRADUATE SCHOOL
MONTEREY CA   R J STAHEL MAR 85

UNCLASSIFIED   F/G 17/2   NL


1·0
2·8
2·5
5·0
3·15
2·2
3·5
2·0
1·1
4·0
4·5
1·8
1·25
1·4
1·6

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN EVOLVING DIGITAL TELECOMMUNICATIONS INDUSTRY AND ITS IMPACT ON THE OPERATIONAL ENVIRONMENT OF THE NATIONWIDE EMERGENCY TELECOMMUNICATION SYSTEM (NETS)

by

Richard J. Stahel

March 1985

Thesis Advisors: Jack LaPatra
and Carl Jones

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A156 831	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) An Evolving Digital Telecommunications Industry and Its Impact on the Operational Environment of the Nationwide Emergency Telecommunication System (NETS)		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis March 1985
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Richard J. Stahel		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, CA 93943		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, CA 93943		12. REPORT DATE March 1985
		13. NUMBER OF PAGES 100
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Digital,
Analog,
Telecommunications,
Nationwide Emergency Telecommunications System (NETS)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Following a national disaster, a Nationwide Emergency Telecommunications System (NETS) would be created by combining the existing telecommunications capabilities of government, public carriers and private networks. This thesis addresses an evolving digital telecommunications industry and its impact on the operational environment of NETS. It contains a comparison of analog and digital capabilities, reviews the digital

#20 - ABSTRACT - (CONTINUED)

telecommunications industry and analyzes the impact of a changing digital technology upon the desired features of a pre-emergency network.

An Evolving Digital Telecommunications Industry
and Its Impact on the Operational Environment of the
Nationwide Emergency Telecommunication System (NETS)

by

Richard J. Stahel
Lieutenant, Supply Corp, United States Navy
B.S., California State University, Hayward, 1976

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN INFORMATION SYSTEMS

from the

NAVAL POSTGRADUATE SCHOOL
March 1985

Author: Richard J. Stahel

Approved by: Jack LaPatra, Co-Advisor

Carl Jones, Co-Advisor

Willis R. Greer, Jr., Chairman
Department of Administrative Sciences

Kneale T. Marshall,
Dean of Information and Policy Sciences

ABSTRACT

Following a national disaster, a Nationwide Emergency Telecommunications System (NETS) would be created by combining the existing telecommunications capabilities of government, public carriers and private networks. This thesis addresses an evolving digital telecommunications industry and its impact on the operational environment of NETS. It contains a comparison of analog and digital capabilities, reviews the digital telecommunications industry and analyzes the impact of a changing digital technology upon the desired features of a pre-emergency network.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

A. BACKGROUND

1. Renewed Interest in Communications Capabilities

From the beginnings of time, when humans first began to clan together and make war on other peoples, man has lived with images of universal Armageddon and mutual annihilation. The nuclear age has enhanced and made more believable this image of total destruction. An interesting paradox is that our capability to inflict massive annihilation has increased at the same time as our expectations of limiting the undesirable effects have become more optimistic. The concept of a "limited nuclear war" has become a by-word for what is considered socially acceptable. What allows this concept to be so intellectually popular is the belief that a war between the superpowers could be fought within mutually agreed-upon limits. Deterrence would be based upon the ability to deal with a variety of potential provocations, with responses tailored to the threat.

Recent political emphasis has been placed on the goal to develop the capabilities necessary to limit a nuclear conflict. This requirement has emphasized the need for a survivable communications system with enough reserve capability to allow for the necessary participants to negotiate a reduction in hostilities.

The concept of introducing limits into a nuclear conflict goes beyond the creation of military and political strategies. While a need exists to determine a viable policy, resulting decisions are mute without a means of practical implementation. The distribution of critical information requires a command and control system which has been planned in advance and is designed to implement the conventions necessary for limiting warfare. The communicative system would have to control thousands of weapons of varying capabilities in the confusion of combat, and make desired limits known to the adversary.

The requirement for effective command and control is critical to the viability of U.S. strategic doctrine. Command-and-control goals are:

a. Provides a means of controlled escalation. Without a survivable means of command, control and communication (C^3), any limited nuclear operations involving discrimination and selectivity would prove infeasible.

b. Has the potential to be a 'force multiplier.' C^3 allows for the optimal use of weapons by gathering data, assisting analysis and permitting the retargeting of weapons. The ability to selectively retarget as the crisis progresses allows for the precrisis retaliatory force to be multiplied beyond what would normally be realized. [Ref. 1]

c. Serves as a means of controlling the degree of the conflict, negotiating and calling a halt to hostilities.

d. Acts as a deterrent to future hostilities. The potential as a 'force multiplier' increases the retaliatory capabilities of the United States and therefore acts as an effective deterrent.

C^3 systems have had operating problems even without a nuclear war raging about them. Several years ago, the

The DSN will be a mixed-media network using both land-line and satellite resources. Numerous programmable switches will be used to exchange routing and control information for both point-to-point and broadcast connectivity.

Mr. R.P. Lippman [Ref. 34], sponsored by the Defense Communications Agency, studied two perspective classes of routing procedures. The performance of these procedures was studied under conditions of network damage, traffic overload and chaotic traffic conditions.

The two classes of routing studied are [Ref. 35]:

1. "Fixed Mixed-Media" routing is the simplest method reviewed. The method uses fixed routing tables and predetermined call-processing rules. A significant characteristic is that satellite and land links are treated separately. The call-processing rules require switches which automatically sense failure or destruction of adjacent nodes. Call-request messages contain a special header which includes a trace of nodes currently in the call path and a listing of blocked or destroyed nodes. Header information is used to prevent loops, avoid inoperative nodes and limit lengths of alternate routes.

2. "Adaptive Mixed-Media" routing is very similar to the Mixed-Media procedure except that when the network is damaged the routing tables are automatically updated to enable optimal usage of remaining resources. Updating procedures are similar to that used in ARPANET, a DOD packet switching network. Each node maintains global information concerning the network's topology. This information is only updated when nodes are added, inoperative or destroyed. This transmission of information for the updating of routing tables must be protected from outside tampering in order to ensure the integrity of the system.

The study can also be applied to "single-media" routing as the majority of the destruction scenarios reflect the loss of satellite capability. The analysis concentrated on a study of four mixed-media network configurations:

II. THE DEFENSE SWITCHED NETWORK (DSN)

This review of a DSN study [Ref. 33] summarizes findings concerning network survivability given various levels of destruction. The evaluation is applicable to this thesis as it demonstrates the desirability of techniques which are unique to digital technology.

A. COMPARISON OF FIXED VERSUS ADAPTIVE ROUTING

The Defense Communications Agency (DCA) is planning to replace the current AUTOVON system with a new network called the Defense Switched Network (DSN). The new system must be both economically feasible during peacetime and have the endurance to provide adequate communications under wartime conditions. The network will utilize both broadcast satellites and point-to-point terrestrial links.

Common channel signaling (CCS) with adaptive network management will be used. Conventional telephone networks have signaling information carried on the same line that carries the speech. Computer controlled networks often use a separate path to carry the required signaling information. With signal separation, the originating station's computer can <u>optimally</u> route the call and not be limited by the path the original signal traveled. The signaling path can also be used to broadcast the information necessary to update routing tables.

C. SYNOPSIS OF FUTURE CHAPTERS

This study reviews the ongoing evolution of digital technology and how it may affect the operational environment of the Nationwide Emergency Telecommunications Systems (NETS). The following is a brief synopsis of future chapters:

Chapter II: The Defense Switched Network (DSN)

A research project, sponsored by DCA, which predicts the survivability of the DSN is reviewed. Comparisons of fixed and adaptive routing indicate the potential difference in capabilities during various levels of resource degradation. The study helps to highlight some of the advantages made possible by digital technology and their application to network survivability.

Chapter III: Digital Versus Analog Technology

A brief comparison of digital and analog technologies is presented. An understanding of the basic differences is necessary to analyze the reasons motivating change in current system architectures.

Chapter IV: Review of the Digital Telecommunications Industry

The quantity, quality, type and compatibility of remaining communications resources depends greatly upon the peacetime policy decisions of commercial telecommunications industries. This chapter provides a review of the motivations and predicted timetable for analog/digital conversion.

Chapter V: Conclusions and Recommendations

a. Analyzes the impact of a changing digital technology upon the desired features of a pre-emergency network.

b. Presents a list of recommendations on ways to influence future telecommunications trends in a manner which encourages the completion of NCS goals.

5. Digital technology takes advantage of recent trends in the miniaturization of computer chips and memory capabilities. Reductions in equipment size and increased energy efficiency have resulted in the creation of more decentralized switching centers [Ref. 28]. These centers increase the survivability of the network by reducing the need for as many centralized switching complexes [Ref. 29].

6. Backup capability has become more affordable as a result of reductions in the price of computing power and memory capability. During an unplanned reduction in system resources, this excess capacity allows for an increased level of recoverability. Within the capacity of the system, the remaining units can assume the work load of the inoperative switching units without any noticeable degradation in user service. This ability to quickly transfer work loads is made possible by the elaborate software systems designed for digital systems.

7. Digital hardware is generally less expensive to purchase and operate than comparable analog equipment [Ref. 30]. This cost advantage is offset to a certain degree by the development costs of digital software [Ref. 31]. If a new system is designed for a large market then the software development costs can be distributed and thereby reduce its impact on an indi-dividual buyer. The problem of increased research costs has its greatest impact during the development stage. The greatest amount of research dollars tend to be devoted to profitable programs which will be demanded by a relatively high number of users.

8. An equipment designer must have access to a large capital base due to the high research costs and long lead time before implementation. Relatively small firms cannot afford to enter into the market for the development and production of digital equipment without significant resources availability. This encourages the merging of efforts by different companies. As foreign companies are eager to obtain new technology and gain a means of competitively entering the U.S. market, there is currently a large influx of foreign capital into the American digital development effort. [Ref. 32]

These changes will impact both the telecommunications industry and the user. The predicted effects will be compared to the attainability of desired NETS' features in the conclusion of this paper.

techniques and the use of 'repeaters' to regenerate the signals, the quality of transmission can be improved to provide a low probability of distorted data. This benefit will increase the overall desirability of distributed processing which can result in even greater demand for digital services. [Ref. 26]

2. The increased efficiency of digital technology will lower the cost of standard services, and strong competition promises to pass these savings on to the customer. The passing of operational cost savings to customers can contribute to the following trends. First, companies with extensive analog equipment may not be able to depend on the benefits of operational cost reductions to finance future equipment conversions. This could provide a significant advantage to competitors with a minimal investment in analog equipment. Secondly, competing firms seeking higher profit margins may tend to stress specialized services tailored to their unique technical advantages.

3. Adaptive routing techniques are made feasible by digital switching. The goal is to reorder real-time routing tables at each switching center based on the success or failure of network probes. This capability increases the potential for modifying communications networks in response to a degradation in available network resources. If a disaster occurs within a limited region, network software allows for the use of alternate paths to circumvent the problem area. This helps to reduce the criticality of direct trunk lines by allowing for the more flexible use of alternate routing.

4. Packet switching and encryption techniques are more practical with the utilization of digital technology. American communications networks are extremely vulnerable to present surveillance methods. This weakness is extenuated by the prevalent use of easily interceptable microwave transmitters. Packet switching increases the difficulty of analyzing these intercepted messages. It creates the additional requirement of recombining a message which may have packets containing portions of the message being transmitted over several different routes. If the use of encryption has been added then an additional level of security has been attained. All else being equal, these countermeasures add to the cost of interception analysis and can reduce the quantity of deciphered communications a surveillance activity can effectively process. [Ref. 27]

the government to implement. Specifically, who will pay for the peacetime inefficiencies incorporated into a system based on wartime survivability requirements? The telecommunications industry will probably press for government relief if forced to move into an inefficient market structure [Ref. 24].

B. IMPLICATIONS OF AN EVOLVING DIGITAL TECHNOLOGY

Technological changes have been influencing the environment in which NETS must be able to survive. Each advancement needs to be analyzed to determine the impact upon the survivability and adaptability of the overall communications network.

This paper considers the effects of an evolving digital technology upon the NETS' operational environment. The following is a list of general areas in which digital technology promises to provide a greater depth of services than current analog systems [Ref. 25]:

1. Transmission Accuracy,
2. Message Routing Flexibility,
3. Packet Switching,
4. Ease of encryption,
5. Increased efficiency in the transfer of digital information.

A summary of predicted changes in telecommunications capabilities follows:

1. Improved transmission accuracy will increase the desirability of transmitting computer data over longer distances. Computer information has proven to be unacceptably vulnerable to long-line transmission distortion. With the advent of digital transmission

which is capable of restoring service that is transparent to the user during a period of degraded resources [Ref. 22].

4. Government Involvement

The capabilities which NETS will have after an emergency is based upon the availability of pre-emergency resources. Before the crisis there should be adequate planning and system modifications to insure that the intended degree of survivability has a high probability of being attained. The following characteristics of a pre-emergency NETS' environment are critical [Ref. 23]:

a. a centralized source of policy and guidance,

b. a sound legislative backing which recognizes the need for the NETS system,

c. adequate budgeting, and

d. government regulations and funding which encourage private companies to modify their policies to meet NETS' standards.

Presidential Directive 53 (PD-53), signed by President Carter in 1979, places emphasis on the use of surviving civilian communications systems for national purposes in a post-attack period. The proposal calls for decentralization and homogenization of future communications systems. While this would prove beneficial for rebuilding a crippled system, it probably conflicts with peacetime commercial goals. Companies tend to stress efficiency through hierarchical organization, operational cost minimization and centralization of certain critical control functions. While PD-53 provides useful guidelines, it will undoubtedly prove difficult for

b. Survivability

1. probabilistically survivable system of adequate nodes and links.

2. personnel and equipment resources for timely reconstitution.

3. minimize transmission distortion created by electromagnetic interference.

4. maintain adequate physical security.

c. Operational Flexibility

1. quickly accessible during an emergency.

2. high user demands can be controlled on a priority basis.

3. protocol flexibility to maximize inter-network compatibility.

4. incorporate adaptive routing techniques to assure that only undamaged routes are selected and to minimize required circuit time per message.

5. responsive to distributed controls with centralized policy and guidance.

6. carry a variety of information.

7. maintain adequate security against unauthorized entry.

NETS' resource capabilities will be attained by combining the telecommunication capabilities of government, public carriers and private networks. It would consist of a nationwide backbone network that would be used to reconfigure required communication routes. In the case of armed conflict, a desired goal would be to interconnect networks to such a degree that the cost of completely destroying them would be prohibitively expensive. A second goal of NETS is to encourage the creation of a telecommunications system

many smaller stations would probably survive and could form the basis for a new network [Ref. 19].

President Reagan has recently expanded the authority of NCS to evaluate and make recommendations on the usage of communication resources during a national emergency. This has stimulated renewed interest within Congress and resulted in the budgeting necessary for continued study [Ref. 20].

3. Nationwide Emergency Telecommunications System (NETS)

A great deal of emphasis has been placed on creating a Nationwide Emergency Telecommunications System (NETS) which would be designed to provide survivable communication capabilities during periods of national emergency. NETS is based on the capabilities existing after a disaster. It is important to understand what the various types of emergencies are, their impact on the environment in which the system must operate, and effects on the communications system itself. NETS stresses the worst case scenario of atomic war, but there are many other potentially disruptive forces of a local nature. NETS covers the study of such diverse topics as hardening of central facilities, protecting personnel, diversity of routes, disaster recovery plans, emergency restoration, etc.

An emergency communications system requires the following technical capabilities [Ref. 21]:

a. General

pre-emergency modifications should be economically feasible.

harsh, post-emergency environment [Ref. 15]. The second alternative is to place emphasis on the survivability of communications assets. Equipment would be designed for its endurance, ease of maintenance and need for minimal support. This would tend to decrease the responsiveness capability necessary for the pre-emergency phase [Ref. 16]. Congress must choose between the conflicting requirements of responsiveness, survivability or the simultaneous achievement of both goals based upon an analysis of perceived benefits and costs. Improvement in both areas is desirable, but cannot be achieved with the same set of investments [Ref. 17]. The amount of required funding, necessary equipment modifications and effect upon the peacetime communications industry varies with each alternative chosen [Ref. 18].

NCS's first objective was to determine the nation's telecommunication assets. Prior to deregulation, NCS awarded a series of contracts to AT&T for determining these assets and evaluating their survivability. The locations of critical nodes were used in conjunction with a damage scenario, developed by the Federal Emergency Management Agency (FEMA), to determine expected levels of damage. The results gave an indication of survivable long-line capabilities resulting form various degrees of disruption. Even after a nuclear attack, substantial communications capability would be expected to exist as commercial telephone networks are extensive and redundant. Although major switching stations would likely be destroyed,

2. <u>National Communications System (NCS)</u>

The National Communications System (NCS) was established in 1963 as part of the Defense Communications Agency (DCA). Its creation was in response to previously unaddressed communication requirements which are grouped as follows [Ref. 14]:

a. Pre-Emergency

1. Provide the means for alerting the National Command Authority in the event of an anticipated emergency.

2. Maintain security and usage controls during periods of increased alert.

b. Post-Emergency

1. Expeditiously reconstruct the communications network.

2. Maintain sufficient communication capabilities to ensure effective command and control.

3. Assist in rebuilding the political, civil and military control structures.

This strategic doctrine suggests two conflicting paths for modernization. The pre-emergency phase requires a high degree of responsiveness in the handling of the initial stages of an emergency. Instead of executing pre-planned attack orders, civilian and military leaders would be able to adapt plans as circumstances changed. The necessary equipment, designed for increased responsiveness, would incorporate a relatively high level of maintenance expertise and effort. The networks utilizing this equipment would have an increased probability of being unable to adapt to the

c. Numerous communications facilities are susceptible to the effects of an electromagnetic pulse (EMP) which would disrupt communications during a period of critical need. Digital equipment is especially vulnerable as it operates with extremely low voltages. A severe electromagnetic pulse could either disrupt traffic or burn out circuits.

As command-and-control systems are inherently vulnerable, concerted attacks on them would very rapidly render them inoperative. The objective is to increase the cost of destroying essential nodes above the threshold which an adversary would deem acceptable. The degree to which this can be accomplished has a direct impact on the extent to which a limited nuclear war could be successfully controlled by a surviving communications network.

The National Command Authorities (NCA) provides guidance to various subordinate commands by use of the World Wide Military Command and Control System (WWMCCS) which consists of a network of command posts, computers and communications links. The more survivable segments of WWMCCS have been designated as the Minimum Essential Emergency Communications Network (MEECN) [Ref. 11]. The system's components were designed to handle peacetime capacity requirements and usually do not have the flexibility determined desirable for a wartime environment. In most cases the bandwidths are too narrow to accommodate the necessary quantities of bulk-encrypted material [Ref. 12]. A great deal of the network is not secure against interception, vulnerable to jamming and has inadequate physical protection [Ref. 13].

Under MAD, C^3 had to maintain its operational capability only up to the point that the President's order for massive retaliation was issued. This is in contrast to the limited war concept where the system survivability is critical to maintain control during an ongoing conflict. While nuclear weaponry capabilities have advanced significantly over the last ten years, C^3 advancement has remained relatively stagnant [Ref. 6].

In 1978, the Hon. William J. Perry, Under Secretary of Defense for Research and Engineering, labeled the C^3 system as "perhaps the weakest link in our strategic forces today" [Ref. 7]. The recognition that the command-and-control network is the most vulnerable portion of the deterrent forces resulted in the Nuclear Targeting Policy Review's (NTPR) conclusion in 1978 that a desired C^3 system "should have greater endurance than the present system" [Ref. 8]. Previous emphasis had been on maintaining command and control for a period of a few days, while the emphasis has now changed to maintaining a command structure for up to a ninety days within a combat environment [Ref. 9].

Existing C^3 communication systems are considered vulnerable within three main areas [Ref. 10]:

a. Critical facilities are too centralized and highly vulnerable to nuclear attack or sabotage. The accuracy of Soviet missiles has increased to the point where virtually any fixed target is assured of destruction.

b. Communications links to nuclear forces are easily disrupted and usually limited to one-way communications during actual hostilities.

U.S.S. Liberty, an intelligence collection ship, was attacked and sunk by the Israeli Air Force because it had failed to receive a direct order from the Pentagon instructing it to retreat from the area of violence [Ref. 2]. Another example was the U.S.S. Pueblo's inability to contact higher authority after four hours of fruitless transmissions [Ref. 3].

The current C^3 system appears to only meet its most fundamental requirement, which is to provide the means for a prompt and massive response to an outside attack [Ref. 4]. This may not prove adequate to meet the limited war concept as defined under the Carter and Reagan administrations. The following are the two contrasting environments in which C^3 may be expected to operate [Ref. 5]:

Operational environment under Mutual Assured Destruction (MAD):

a. surprise first attack is presupposed,

b. time period of attack lasts a few minutes,

c. probable targets are urban and economic centers,

d. post-attack requirements limited to civilian recovery and continuation of government.

Operational environment under the Limited War Concept:

a. gradual build-up to hostilities is anticipated,

b. time period of attack lasts from a few days to a week,

c. initial attacks restricted to military targets,

d. the necessity exists to provide centralized guidance to military commanders and civilian leaders during a period of continued conflict.

1. DSN1--20 nodes

2. DSN2--40 nodes

DSN1 and DSN2 have no spare trunking to increase survivability.

3. DSN3--20 nodes

4. DSN4--40 nodes

DSN3 and DSN4 include reserve terrestrial trunk lines which increase system cost by approximately 10%. These additional trunks are designed to provide supplementary paths to compensate for the destruction of the system's satellites during wartime conditions.

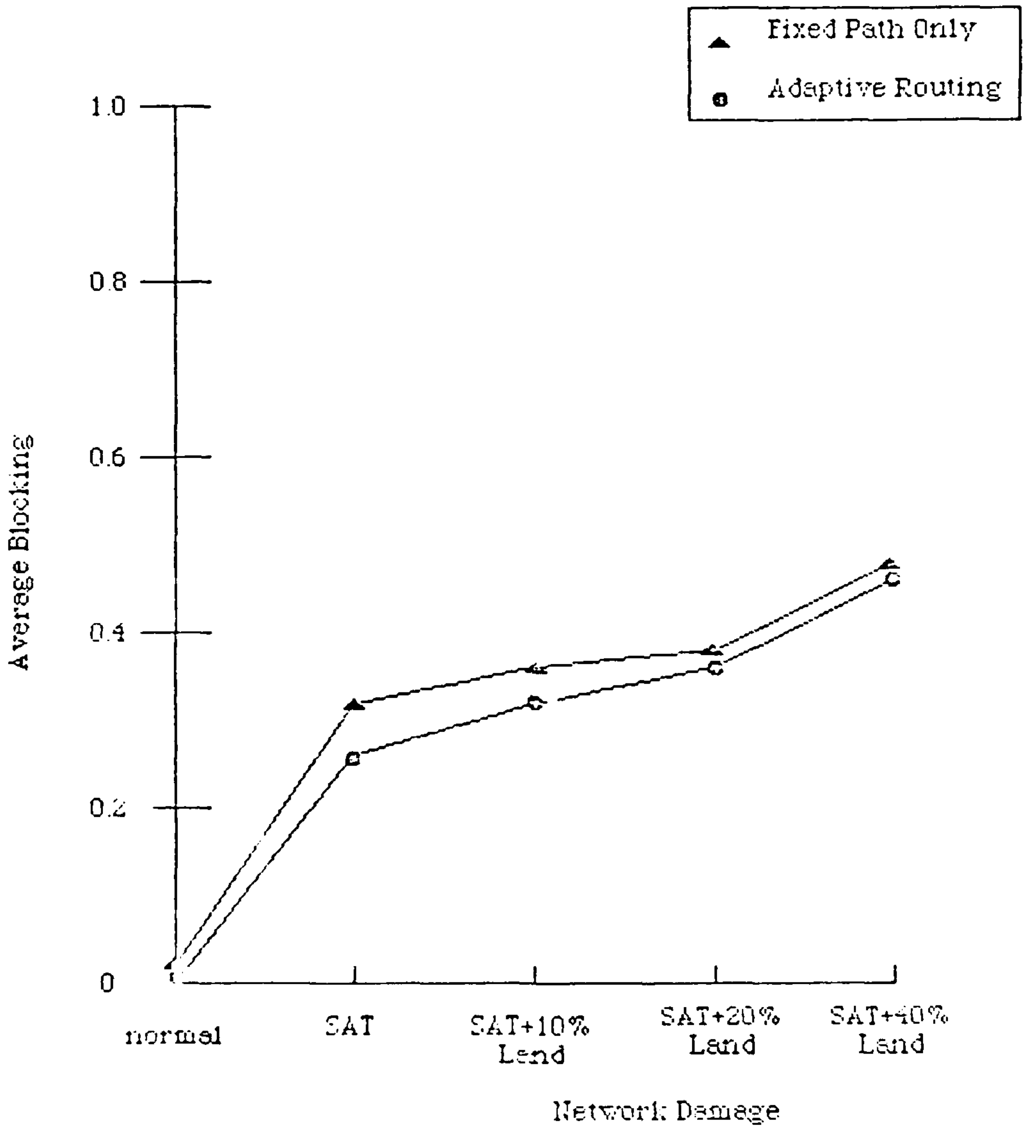
Traffic loads were based upon a tentative 100 node DSN configuration used during system design. The models were created by selecting the nodes with the highest level of outgoing traffic. One third of all traffic was transmitted over satellite links.

The four networks were analyzed under the following conditions:

1. normal operating conditions,
2. different types of network damage,
3. varying traffic loads, and
4. chaotic traffic patterns.

Figure 2.1 reflects the average point-to-point blocking probability predicted for DSN1 under normal conditions, satellite destruction, and satellite plus 10%, 20%, and 40% terrestrial line destruction.

Under normal operations, an average blocking probability of less than .02 was attained. With satellite destruction,



[Ref. [illegible]]

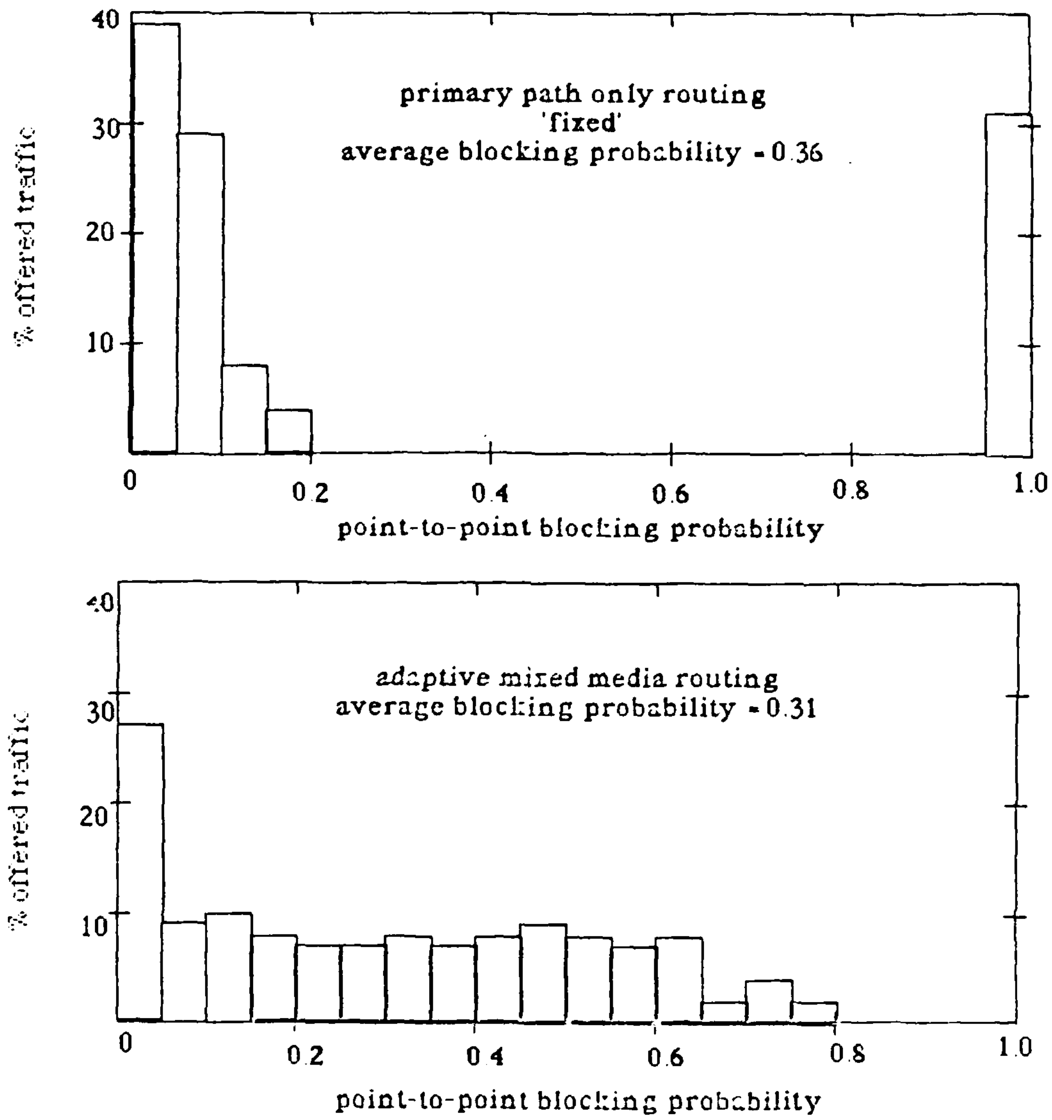
Figure 2.1 Average Point-to-Point Blocking Probability for Various Levels of Network Destruction

the degree of blocking increases substantially and continues to increase as a greater proportion of the land lines are destroyed.

Figure 2.1 reflects essentially no difference in the performance of the two previously mentioned routing methods. Fixed routing has an average blocking probability of 0.36 and adaptive routing has an average blocking probability of 0.31. The varying impact of each method was only revealed after comparing the percentage of offered traffic against the probability of blocking, given satellite destruction, as shown in Figure 2.2.

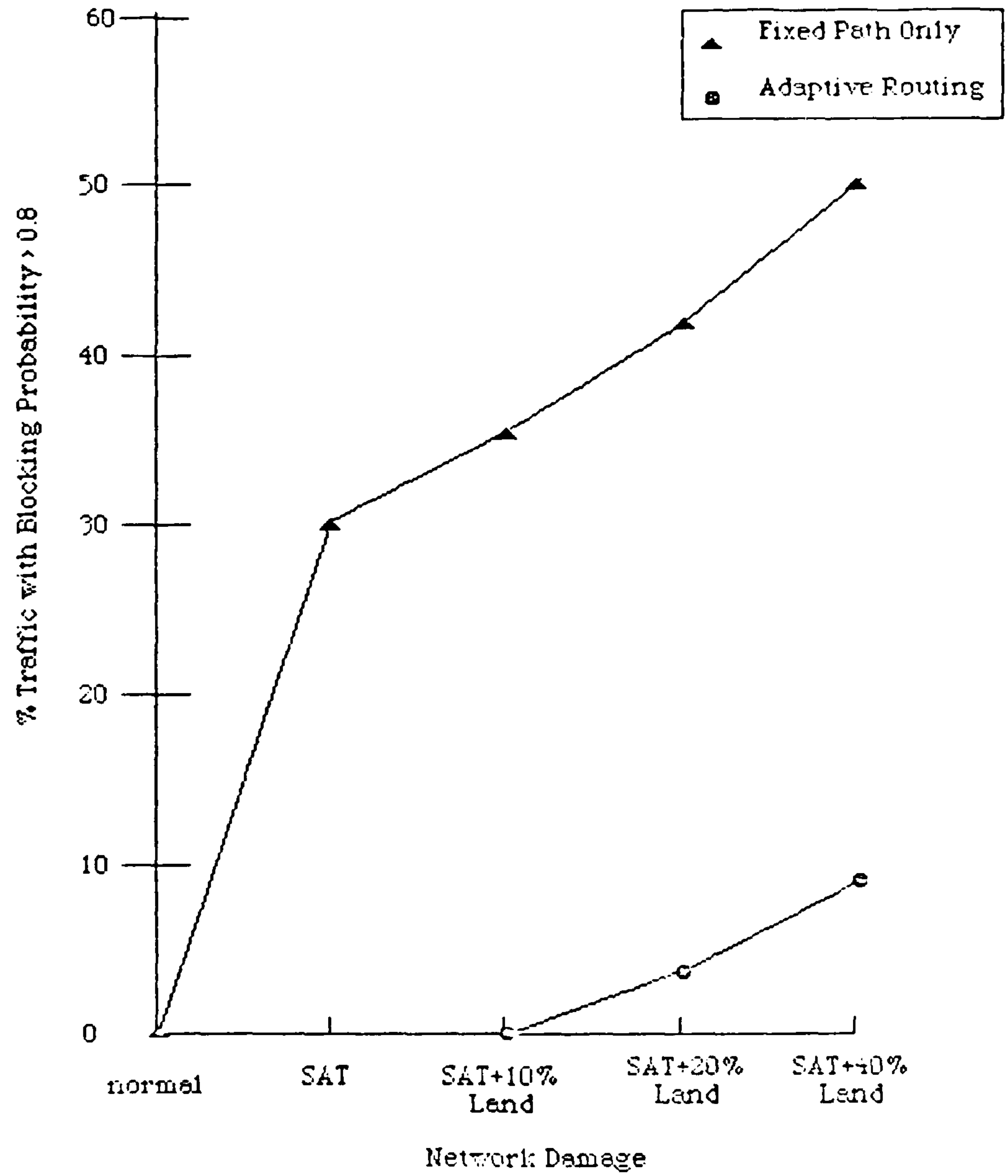
As previously noted, the satellite component of the model carries one-third of the traffic. With its destruction, the traffic load of terrestrial lines correspondingly increases. While the cumulative blocking percentages were relatively equal for the two systems, Figure 2.2 indicates that approximately one-third of the traffic routed by the fixed method experienced a blocking probability of 95%. This is significantly higher than that attained by the adaptive method which treats all nodes more uniformly. The ability to adapt routing tables allows for the placement of calls between any two nodes with only occasional blocking probability reaching 80%.

Figure 2.3 reflects the percentage of fixed and adaptive traffic with blocking probability in excess of 80% for each of the five levels of destruction.



[Ref. 37]

Figure 2.2 Point-to-point Blocking Probability Histogram for when the Satellite is Destroyed



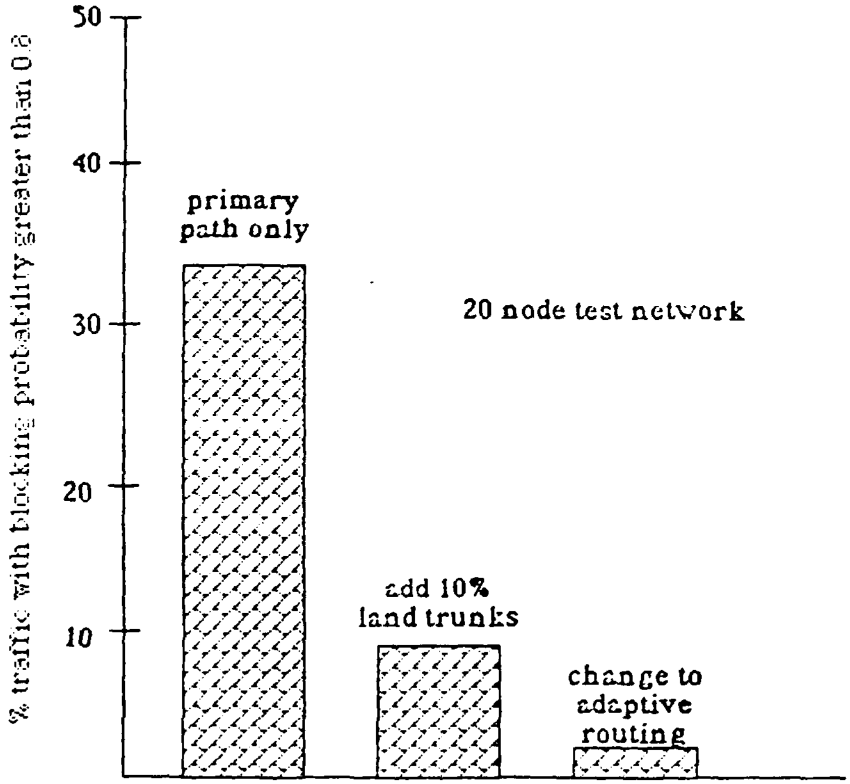
[Ref. 38]

Figure 2.3 Percentage-Offered Traffic with Blocking Greater Than 80% compared to Damage to Satellite and Trunk Lines in Network DSN1

For the purpose of his study, Mr. Lippman set an 80% level of blocking as the limit of acceptability for the first attempt at placing a call. Figure 2.3 demonstrates the disparity between the level of acceptability attained by the two routing methods. When only the satellite is destroyed, the terrestrial lines are able to maintain an adequate level of performance under adaptive routing, but fixed routing has 31% of its traffic suffering an unacceptable level of blocking. As the degree of damage increases, the percentage of unacceptable performance increases for both routing methods. With the satellite and 40% of the terrestrial lines destroyed, fixed routing provides acceptable service to only 48% of its users while adaptive routing attains 92% acceptability. Adaptive routing clearly provides a higher level of service for all scenarios reviewed.

By reviewing each of the four network configurations, DSN1-4, comparisons were obtained between the fixed method, fixed method with a 10% increase in trunks, and adaptive routing methods. Figure 2.4 compares the three configuration alternatives with the percentage of traffic having a blocking factor in excess of 80%. The level of blocking probability reflects the destruction of the satellite with the resulting one-third increase in terrestrial traffic.

With the fixed routing method, approximately 33% of the traffic experiences unacceptable blocking. This level can be reduced by increasing the number of trunk lines or using



[Ref. 39]

Figure 2.4 Percentage of Offered Traffic with Blocking Greater than 80% when Satellite is Destroyed for (1) Fixed Routing, (2) a 10% Increase in Land Trunks and (3) the Original Configuration with Adaptive Routing

adaptive routing techniques. With the addition of 10% more trunk lines, the percentage of unacceptable blocking drops to roughly 8.5%. With the implementation of adaptive routing techniques to the original configuration, the rate drops to almost 0%. For the Defense Switched Network, increasing trunk capability by 10% costs more than modifying the system for the use of adaptive routing.

Additional studies were conducted for various levels of traffic overload and chaotic traffic patterns with similar findings. The results of the study indicated that adaptive routing provided the highest degree of service for all levles of disruption reviewed.

B. CHAPTER SUMMARY

The study indicates that adaptive routing procedures are desirable for both responsiveness and cost effectiveness. An important assumption is made that an all-digital network system is already in place.

The advantages of a digital system over the traditional analog methods is discussed in Chapter III, "Digital versus Analog Technology." The likelihood of an all-digital system and the rate of transition is addressed in Chapter IV, "Review of the Digital Telecommunications Industry."

III. DIGITAL VERSUS ANALOG TECHNOLOGY

An understanding of the basic differences between analog and digital technology is necessary to analyze the reasons motivating change in current system architectures.

A. DESCRIPTIONS AND COMPARISONS

1. Definitions

a. Analog

Vocal cords generate sound waves with frequencies varying from a few hundred cycles per second to several thousand cycles per second. The telephone's microphone converts these sound waves to a varying electrical frequency which is analogous to the sound frequency [Ref. 40]. The electrical signal is an analog of the voice frequency. Hence, an analog transmission system is one that accepts a variable input and then represents it electronically as a continuous signal to be transmitted and decoded by the receiver [Ref. 41].

b. Digital

With digital transmissions there is a 'discreteness' in the signal which allows information to be transmitted by deviating the strength of the signal from a predefined norm. A combination of different discrete impulses can then represent information in transit.

Transmission is accomplished by the creation of two signal levels which indicate the binary digits of one and

zero. For example, assume that zero volts represents a binary zero and five volts represents a binary one. When a binary zero is transmitted, a signal level of zero volts is transmitted. When the signal is finally received it will have picked up a degree of distortion. Because of line noise the actual voltage level may slightly exceed zero volts. As long as the variance is within previously set limits, the signal is interpreted as a zero. If the signal must be retransmitted, it is once again set to a zero voltage level, essentially elminating the distortion. By this means a signal can be retransmitted several times over a long distance with the final signal being as distortion-free as the initial message [Ref. 42].

Digital communication, by its very nature of discreteness, is adaptable to the transmission of information such as computer data, graphics, voice or even machine instructions.

c. Digital Transmission

In contrast to an analog signal, a digital signal, while in transit, can not only be amplified but also detected and regenerated. As previously stated, this allows for the signal regeneration necessary for long distance hauls where only the information media is amplified and distortion is ignored. Another attractive feature of voice digitalization is the divorcing of encoded signals from the analog waveform of the source. This allows for the digital transmission and

switching equipment of a network designed for voice transmission to also be capable of servicing any traffic of a digital nature.

d. Digital Switching

Digital switching refers to the use of digital technology 'within' the message path of voice communication networks. In this application, the term 'digital' refers to a method by which the conventional analog voice information is sampled, categorized and electronically converted by coding to a digital signal. Hence digital communications technology implies the capability for both information transmission and switching applications versus the generally held belief that it is limited to the transmission of computer generated data.

While operating within a hostile environment most switching configurations are:

1. Vulnerable to fragmentation: Switching systems are designed to interconnect various levels of the telephone system hierarchy at the local, regional and national levels. This method is vulnerable to disruption when failure at the national or regional level could fragment the network into isolated subsystems.

2. Unable to dynamically route in response to changing line conditions: Centralized systems are unable to monitor the global status of the network due to the high overhead required. A significant portion of the transmission bandwidth must be available for sending status on thousands of nodes.

3. Vulnerable to flooding by routine calls which would block priority communications: In order for priority calls to be recognized they must first enter a local switch for processing. If initial entry cannot be attained, there is no way to recognize a caller's precedence. This conflict places emphasis on the

traffic load capability of the system for the determination of priority levels. The number of simultaneous calls in a system is limited by the number of available network ports. All traditional analog networks have built-in limitations on the number of ports which the system can handle. The pulse-code modulation (PCM) digital networks have only recently allowed full availability. However, in an attempt to remain compatible with present analog equipment, several digital switching products are designed to incorporate techniques based upon limited access. [Ref. 43]

An alternative to the present centralized method of switching is called Gridnet [Ref. 44]. Vulnerability is decreased by distributing network control functions to the various nodes. Instead of maintaining global status tables, each node would only be concerned with the condition of its neighboring nodes. This technique requires only a small fraction of available bandwidth for status transmission. The main advantage is that if any two nodes are connected after a disaster then a message can be sent. The disadvantage comes from the lack of global information which may result in a nonoptimal path selection.

The only existing switching system which uses fully distributed control is ITT's System 12. Control is spread throughout the system and not locked into a central computer. Therefore a problem in one area can not expand to other areas. Due to its fully digital integrated circuits, System 12 can have prearranged handling routines for heavy traffic loads. Nineteen countries have ordered 11 million equivalent lines of System 12 [Ref. 45].

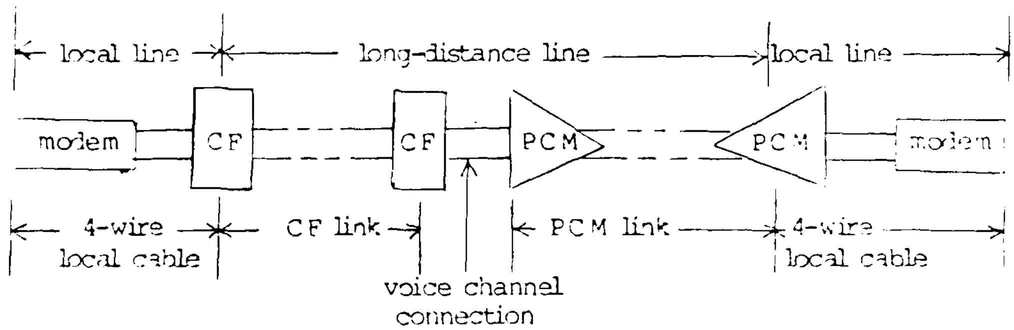
2. Typical System Configurations

a. Analog

Definitions for Figure 3.1:

a. Carrier Frequency Equipment (CF) consists of the transmission linking apparatus.

b. Pulse Code Modulation (PCM) is a process where an analog signal is sampled, the magnitude of each sample is quantized, and the quantized value is converted to a digital signal.



[Ref. 46]

Figure 3.1 Typical Analog Network Structure

The analog approach offers an uncomplicated method of implementing the circuit. If the user purchases the modem, no expenses arise for the administration. Variable costs are limited to charges for the use of the analog lines and infrequent maintenance.

b. Digital

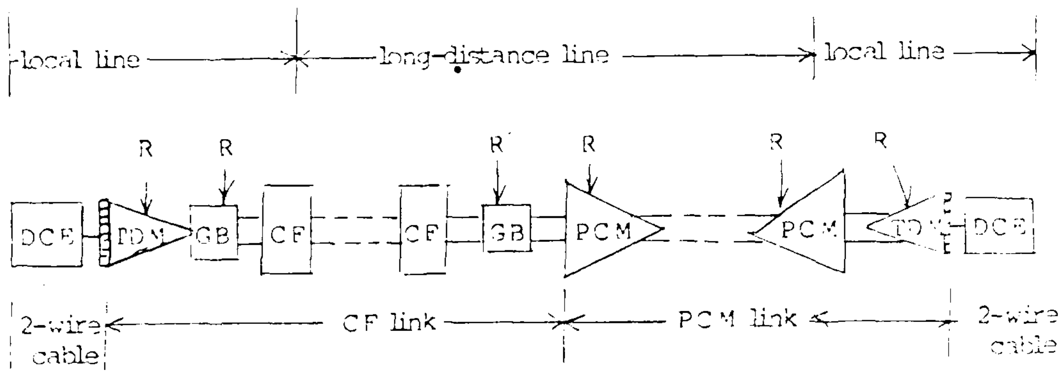
Definitions for Figure 3.2:

a. Data Circuit-terminating Equipment (DCE) transforms data received from user terminals into a suitable form for transmission over the network.

b. Time-Division Multiplex (TDM) allows the transmission of two or more signals simultaneously over a single transmission facility.

c. Group Band Model (GBM) is used to switch trunks in a manner to minimize transmission length and minimize noise introduction.

d. Signal Regenerator (R) reduces noise by analyzing an incoming signal and then re-transmits it in its original digital form.



[Ref. 47]

Figure 3.2 Typical Analog Network Structure

Initially the digital approach seems to be more complex and costly. This first impression is based on an empirical view of the two system structures. However, it does offer technical and economic advantages. A comparison between the two systems is the basis for the remainder of this chapter.

3. General Comparisons

The following is a summarized comparison of analog and digital operational features [Ref. 4[illegible]]:

Motivations for digital communications:

a. Digital technology provides improved trans.ission quality. Repeaters allow for the signal to be regenerated at predetermined distances to provide an overall transmission quality independent of distance. Within limits, this allows for transmission quality to be progressively increased by the usage of additional repeaters. This cumulative effect in performance does not apply to analog systems where distortion becomes an inhibiting factor. [Ref. 89]

b. Reliability is another factor which justifies digital systems. It is not that the digital system is more reliable. The advantage is that the same level of reliability can be obtained with digital technology at a smaller expense [Ref. 90]. Both digital and analog systems have a design objective of one hour down time in twenty years of operation [Ref. 91]. At least three factors contribute to the ability of attaining acceptable digital reliability levels at a reduced cost:

    1. The heavy use of large scale integration (LSI) circuitry. Incorporating the thousands of components on an integrated circuit chip means that many solder joints are eliminated and, thereby, reliability is increased. Another by-product of LSI is the relatively low power required. Manufacturers are now beginning to make use of Complimentary Metal Oxide Semiconductor (CMOS) technology which has the characteristic of even lower power consumption than that required by LSI circuitry. [Ref. 92]

    2. Digital technology is more reliable for the transmission of signals by being less susceptible to distortion (noise) than analog technology. [Ref. 93]

    3. As the cost of circuitry goes down it is possible to maintain duplicate modules to replace ones requiring repair. Given excess capability, if a unit goes down then its share of the work load can be rerouted to other portions of the system without any noticeable degradation in service.

c. Provides an ability to add new features. The digital transition represents an opportunity to evolve into more unified networks capable of accommodating various types of traffic. Additional services can include the transmission of video signals or computer data.

2. Motivations for Digital Communications

The silicon chip has become a driving force behind many trends in the telecommunications industry, and public policy is being both shaped and adapted to those trends. Devices like microprocessors, memory and other logic elements are rapidly dropping in price. The development of these relatively low-cost digital electronics has enabled economical use of a new and, in many cases, superior technology for conventional voice telephone systems. In addition, new ways of moving digital information, such as microwave radio, satellites, and optical fiber cables, are dramatically lowering the cost of sending messages across vast distances.

Many forces driving digitalization are based upon a desire to improve quality of transmission, add new features, and reduce the operational costs. The need by the data processing industry for better data transmission capabilities has 'not' been the major motivating force to date. In fact, the majority of digital capability is inaccessible to data processing transmission without going through analog interfaces. As the networks incorporate more digital capabilities the economics of data transmission should improve. It has been estimated that between 5 to 10% of the total traffic on the telephone network is computer data [87]. This percentage will grow in the future as more cost-effective services are offered, but currently the transmission of computer data is a secondary motivating force behind digital communications [Ref. 88].

levels of the switching hierarchy of the public telephone network is commonplace today. The list of modern switching systems for major exchanges currently being offered in world markets now totals only thirteen families, all of them digital [Ref. 84].

Digital line-transmission is more difficult to implement as distances increase, but even with great distances there are distinct advantages [Ref. 85]. It is predicted that digital conversion of long distance routes will not occur as fast as the conversion of local routes connecting adjacent cities. To date only 4% of the public network's long-distance circuits have been converted to digital format. Prior to deregulation, AT&T had plans to convert 35% to 40% of its network to digital by 1990 [Ref. 86]. This included plans for undersea cables capable of digital transmission to both Europe and Japan.

The Department of Defense (DOD) has tended toward the use of digital communications as a standard for both tactical and strategic networks. This decision is based on the inherent advantages provided by the actual equipment such as reduced weight and size, easier maintenance, and less power consumption. Of major significance is the ability to satisfy communications security by providing transmissions in digital format which allow for easier and potentially more secure encryption.

their older analog systems with digital equipment to handle everything from individual telephone calls to computerized airline reservations [Ref. 77].

The economic and operational features of solid state electronics are the deciding factors which make the digitalization and transmission of data feasible. In 1962 Bell System personnel pioneered the use of a T1 carrier system for its trunk routes based on digital equipment. After this initial test, a whole family of T-carrier systems have been developed. The world's first commercially designed digital microwave radio system was implemented in Japan by Nippon Electric Company (NEC) in 1968 [Ref. 78]. France was the first country to use digital switching in their public telephone system, the ALCATEL E10 [Ref. 79]. In the early 1970s digital microwave systems were beginning to appear in the United States for specialized applications. The first digital microwave link in the U.S. public telephone system was purchased from NEC of Japan to provide a communications link between Brooklyn and North Staten Island in 1972 [Ref. 80].

During this same time frame, but largely independent of work on speech digitalization, the use of digital computer techniques was being applied to the control of switching systems [Ref. 81]. The resulting 'stored program' method of controlled-switching architecture has been widely deployed in recent years [Ref. 82]. The flexibility inherent in 'stored program' control results in a high degree of modularity of functions [Ref. 83]. Computer control of the switches at all

IV. REVIEW OF THE DIGITAL TELECOMMUNICATIONS INDUSTRY

NETS' capabilities are determined by both the military and civilian resources which survive an emergency. The quantity, quality, type and compatibility of these remaining resources depends greatly upon the peacetime policy decisions of commercial telecommunications industries. This chapter provides a review of the motivations and predicted timetable for analog/digital conversion.

A. BACKGROUND

1. Historical Summary

A nation's telecommunication capability is considered essential for maintaining a productive business climate [Ref. 75]. As the business environment increases in complexity, the transmission of accurate and timely data becomes crit . The degree of effectiveness in the transfer of data between commercial enterprises could provide a significant business advantage. With the importance of international competition increasing, the maintenance of a viable telecommunications industry is growing in significance [Ref. 76].

A technical revolution is occurring within the world's networks. Recently implemented digital equipment promises to reduce operational costs and increase the variety of available equipment. Telephone companies are methodically replacing

6. Performance Monitoring

Each digital signal has a predetermined scale of acceptable signal levels. This is important, as it allows for quality verification tests without any knowledge of the actual message contents. One common way to measure the performance of digital systems is to add parity bits to the message stream. This is in contrast to analog systems where a predetermined message must be sent over a line to determine performance parameters. This transmission necessitates the isolation of the line from commercial use.

C. CHAPTER SUMMARY

The advantages and disadvantages of each system were discussed. As neither method is always optimal, each application must be reviewed to determine the alternative which meets both requirements and cost limitations.

The relevance of digital and analog characteristics will be addressed in the conclusions by comparing them with the unique objectives of NETS.

readily adaptable to a digital system. For analog systems the input must be either converted to a compatible analog input or a dual transmission signal. Analog signaling has traditionally represented a significant cost and administrative burden to the telephone companies. The ability of digital systems to transmit control information by the simple addition of information bits to the message stream represents a significant benefit.

5. Signal Regeneration

The accuracy of analog signals degrades as a function of transmission length. Distortion increases with the path length, and power boosters indiscriminately increase both the intended signal and the accumulated distortion. This is in contrast to digital signals which are discrete versus continuous. When they begin to deviate from their excepted limitations, regenerative repeaters can be used to duplicate the signals 'within' the original tolerance levels. By this method, the probability of transmission errors can be made arbitrarily small by the insertion of enough regenerative repeaters at various points in the transmission path. When an all digital system is designed with enough repeaters, the overall quality of the transmission is determined by the digitalization process and not by the transmission system [Ref. 74]. This presents a significant advantage to the all-digital transmission of computer data. The probability of transmission errors can be reduced below that attained by systems with analog components.

switching centers are becoming technically similar to other commercial computer sites, the skills of the maintenance center can be contracted out or used internally by other departments.

2. Analog-to-Digital Signal Conversion

The conversion of signals from one form to another introduces a source of distortion. This is due to the fact that the continuous analog waveform must be represented by finite digital signal levels. By specifying digital signal levels which are small enough, the degree of conversion error can be reduced. Unfortunately, the consequence of more levels is the necessity for greater bandwidth. This relationship results in a trade-off between quality of transmission and required bandwidth [Ref. 72].

3. Low Signal-to-Noise/Interface Ratios

In analog systems the greatest line distortions are realized during pauses in audio input when the signal amplitude is low. Since the signal is at a low power level, outside influences acting on the signal are most evident. This is not the case in digital transmissions where speech pauses are electronically encoded the same as normal speech patterns and transmitted at the same power levels [Ref. 73].

4. Control Information

Control information is required to send relevant external information (such as whether the phone is off the hook, coin deposits, etc.). This type of information is

large scale integrated LSD circuits become more available for telecommunications applications. With implementation of LSI there should be further advantages realized in size, energy/acquisition costs and reliability improvements.

Digital transmission and switching are designed for integrated operations. Numerous alarms are built into both systems, giving details on the various phases of each operation. This enables digital exchanges to take into account performance variations when determining optimal routes. In such situations the maintenance staff is kept fully informed of actions taken by the software to compensate for various anomalies. A more efficient maintenance effort can be realized with a minimal crew by taking advantage of such an integrated system.

Digital exchanges consist mainly of plug-in boards. Self diagnostic programs can usually determine the defective board which is the cause for degraded service, and a relatively inexperienced service crew can remove the board and forward it to a maintenance center [Ref. 70]. It is now becoming common practice for exchange maintenance duties to be centralized with one center looking after many exchanges; 60 exchanges or 250,000 lines is not an uncommon top figure. One man-year of maintenance staff effort for every 20,000 lines of capacity is an average for modern exchanges, so the number of technicians needed is nowhere near as great as was once the case [Ref. 71]. In addition, as telephone

c. attenuation (frequency response) and delay distortion is maintained at a level considered adequate for analog communications.

d. echo problems due to transmission delay caused by the 2/4-wire hybrid circuits.

e. connection noise is not related to distance as in analog techniques but to the number of analog/digital conversions. [Ref. 66]

3. Digital signals must be synchronized by means of a special timing clock. This requirement for synchronized transmissions can cause problems during complicated networking situations. [Ref. 67]

4. Digital switching introduces certain problems to the maintenance organization, such as [Ref. 68]:

   a. Increases the probability of the entire exchange, or a major portion of it, being out of service due to a failure of the centralized control circuitry.

   b. The use of processors and peripheral equipment increases maintenance complexity.

   c. Creates a need for software expertise.

   However, the availability of automated maintenance aids combined with the high reliability of digital switches makes the systems less prone to breakdown. [Ref. 69]

5. Maximum benefits are only realized when the system is fully digital. This situation is rare in an environment rich in analog equipment.

B. RELEVANT TECHNICAL FEATURES

1. Electronic Circuitry

Recent advancements in computer technology have had a significant impact on digital transmission and switching capabilities. Many switching applications can use standard central processing unit (CPU) chips and memory devices without any modification. Future benefits are predicted as

5. Disadvantages of Each System

a. Analog

1. Cannot take full advantage of newer technology such as packet switching.

2. Does not accommodate the transmission of computer or graphic data as efficiently as digital communication. Low speeds in the range of 300-2400 baud are easily handled through normal telephone networks. However, higher speed data transmissions are more efficiently handled by digital techniques. [Ref. 62]

3. Fewer viable options for the reduction of distortion. [Ref. 63]

4. Less timely interface repairs for the transference of data (computer, graphic and video data). When a fault is detected within an analog system, isolation of the problem generally takes longer than in a digital system. Modems place great demands on the parameters used to determine system status. Analog circuits can only be checked by a complex evaluation of the conversion process between the model and the network [Ref. 64]. This raises difficulty in defining the area of responsibility if the modem is privately owned and connected to a service network. As a pure digital system operates without a modem, there are no complicated interface problems.

b. Digital

1. For long-haul systems, digital communication systems may be significantly inefficient in terms of the number of voice channels available per bandwidth size. However, the ability to overcome many forms of distortion can compensate to some degree. Long distance costs can be further reduced by the use of packet switching, which would improve network efficiency.

2. While operating within an analog environment, the following digital transmission limitations are encountered [Ref. 65]:

   a. transmission capacity is limited to the bandwidth of the voice channel.

   b. expensive modems (interfaces) are necessary for signal conversion.

reduces complexity, training requirements, potential for repair errors and inventory costs.

8. Electronic components are at least one thousand times faster than the mechanical ones now in use. This allows for either the time-sharing of unused capacity or reduces circuit complexity.

9. Potential for service integration. Control information (i.e., toll charges, busy signals, etc.) is readily adaptable to digital systems. Transmission of control information had previously been an independent consideration. [Ref. 58]

10. Electronic Switching Technology (EST) offers many advantages over earlier electromechanical systems. It provides greater processing speed, capacity and reliability while also reducing overall size, cost and energy requirements. Stored Program Control (SPC) allows for the flexibility of EST. SPC consists of software designed to allow for specialized switching and compatibility requirements. [Ref. 59]

11. Simplifies integration of transmission and switching which have traditionally been separate functions within the telecommunications industry. With the advent of digital technology, multiplexing can easily be integrated with the switching function. This enables the interconnection of switches and transmission links without the requirement for a conversion process [Ref. 60]. This simplification results in considerable cost savings and improvement in performance.

12. Monitoring of performance. Digital output can be analyzed for quality of transmission without any knowledge of the message content. One common method to measure digital transmission quality is to add parity bits to traffic. Analog performance measurements require the use of prespecified monitoring messages which decrease network efficiency.

13. Digital technology allows for the efficient use of encryption techniques in combination with packet switching. The combination of these two techniques provides for a higher degree of security than can be attained by a comparable analog system. If packet switching is not utilized, then a digital means of encryption does not normally meet the security level attained by an analog system. [Ref. 61]

b. Digital

1. Digital transmission systems became cost-effective in the 1960s for relatively short distances, and the range has been increasing with the passing of each year. Digital switching has become cost effective in most situations including analog environments. [Ref. 52]

2. Digital technology is compatible with fiber optics which offers the following advantages [Ref. 53]:

   a. capacity for transmitting huge quantities of information,

   b. connecting lines are immune to electromagnetic interference (although repeaters are vulnerable),

   c. able to transmit light pulses farther than copper can carry an electrical signal with fewer repeaters,

   d. smaller and lighter in comparison to copper wire.

3. Digital systems can accommodate communication services other than conventional speech transmittal. Such information services include data, graphics, video transmissions and machine instructions.

4. Analog nodes are usually located at the user's location, while digital systems have their node equipment installed at the local exchange. The centralization of node functions tends to ensure a more economical configuration and increased transmission quality. [Ref. 54]

5. Noise (interference) does not accumulate at repeaters and thus becomes a secondary consideration in system design. In fact, the output signal is cleaner than the input. This is in contrast to analog systems where noise is of major concern. [Ref. 55]

6. The digital format of transmission adapts easily to solid-state technology and integrated circuits. This allows for greater use of developing computer technology. [Ref. 56]

7. Digital equipment has more common circuitry [Ref. 57]. Due to the enhanced ability of digital circuits, they are designed to accomplish tasks which may vary slightly between different equipment models. This allows for the same circuit module to be used where different analog parts were previously required. This commonality

ANALOG	DIGITAL
switches waveforms in analog form by means of analog components such as transistor relays, etc.	switches waveforms in digital form and uses logic gates or memory
switches are expensive and bulky	switches are smaller and relatively inexpensive (affected by the continuing decline in the cost of microprocessors and memory)
line interfaces are simple (all analog)	line interfaces are usually complex due to analog/ digital conversion
conventional network designed to obtain maximum bandwidth efficiency for an analog system	bandwidth limited (greater bandwidth required than many of the current transmission lines now offer)
line acquisition costs are relatively low (generally wire-pairs)	line circuit costs are high (generally coaxial cable, four wire or fiber optics)
network costs are relatively high	network costs are relatively low
requires substantial space	less space required (size savings can defer new construction)
difficult to expand due to multistage configurations	large expansions can be configured easily (common modules can be installed with less effort and expertise)

4. Advantages of Each System

a. Analog

1. Limited signal conversion is required to interface with the numerous analog systems currently in use. This is in contrast to digital systems which often require expensive conversion techniques. [Ref. 49]

2. Generally requires less bandwidth which reduces long distance transmission costs. [Ref. 50]

3. Analog encryption usually has higher speech quality, lower cost, less channel requirements and greater flexibility than digital encryption techniques. [Ref. 51]

d. Digital technology allows for a reduction in the cost of most standard voice services. While the software necessary for digital switching is expensive, factors such as reduced hardware costs, lower power consumption and greater maintainability have driven the overall price of digital systems downward [Ref. 94]. This reduced price applies to a specified level of service. In general, individual rates have increased as customers take advantage of the greater services available and changes occur in subsidization policies.

3. Factors Limiting the Rate of Analog/Digital Conversion

Considering the massive amount of analog equipment now in place, an extensive conversion period will pass before the public networks in the U.S. can evolve to an all digital system [Ref. 95]. However, as new private networks are developed, all digital implementations will become economically feasible for companies which are not handicapped by large investments in analog equipment.

Factors inhibiting rapid conversion of public networks to digital technology:

a. Digital conversions must fit into a predominantly analog world.

   1. Almost all end user equipment was analog until just recently when digital instruments became available in limited quantities. [Ref. 96]

   2. The great bulk of the transmission and switching facilities of the telephone companies are analog although the number of digital switching and transmission facilities is growing rapidly. [Ref. 97]

b. Most manufacturers have a vested interest in analog systems because of existing analog product lines. Additionally, their design engineers and maintenance people are more familiar with analog systems. With the increased production of digital equipment this factor is becoming less significant. [Ref. 98]

c. Digital software costs account for about 75 percent of the development cost [Ref. 39]. The cost of developing both the hardware and software required for digital systems is significantly higher than that needed for analog equipment. This necessitates appealing to a large customer base to distribute the cost of software development. [Ref. 99]

d. The absence of adequate long-distance transmissions facilities for digital signals. In the near future this may be alleviated to some degree by the use of fiber optics and satellites. Digital communications' optimal use of satellites has been hindered by the relatively long delay periods necessary between packet transmission and verification of receipt. This delay has tended to complicate standard packet switching techniques.

B. MARKETPLACE FORCES

1. Background

Computer technology has allowed for the practical implementation of digital networks. These new capabilities have given the potential for the lowering of standard charges and increases in the number of services offered. As wider services become more prevalent and beneficial, telecommunications has the capability of becoming an even more important strategic weapon to competing organizations. In order to remain competitive, companies are demanding more from their communications systems.

The publishers of Telecommunication Products Plus Technology conducted a survey of 9500 organizations to determine their viewpoints concerning telecommunication service options. Table I is based on the responses received from 1,558 of those solicited [Ref. 100]:

TABLE I

TRENDS IN SPECIAL TELECOMMUNICATION APPLICATIONS

	Currently Use %	Plan to Use %	No Plans to Use %
Alternative Carriers	50	22	28
Microwave Communications	29	20	51
Satellite Transmission	18	20	62
T1 Systems	19	28	53
Fiber Optics	14	44	43
Teleconferencing	25	38	37

[Ref. 101]

User demand for varied services motivates change, but is not the only influencing factor. Providers of communications services are switching to digital for projected operational cost savings. Given the same degree of service, digital technology is less expensive to procure and operate [Ref. 102]. To maintain a competitive cost structure in a deregulated environment, the conversion to digital technology is a necessity.

Two basic approaches are possible for conversion of the present public systems to an all-digital capability. First, entirely new digital systems can be constructed similar to the projects being started by small, private firms.

Unfortunately, the writing off of currently owned analog equipment would represent a significant financial handicap to the public networks. Secondly, the more commonly accepted alternative is allowing digital systems to be implemented over a longer time span. This method would allow for the phased replacement of analog equipment, but would also entail extensive conversion expenses and delay expected benefits. These expenses affect the public utilities' ability to compete with all-digital competitors [Ref. 103].

The balance between increasing available services and lowering costs is a delicate one. As the degree of services offered increases, the cost of an analog, digital or hybrid system will correspondingly increase. While many user companies have a demand for extended services and can justify the additional costs, it could be viewed as a disadvantage to a smaller company. This dissatisfied client may seek service from a more specialized communications firm offering basic services at a cheaper price. If the number of customers using the additional features do not generate enough revenue to compensate for the additional capital expenditures then general usage rates will rise for all other customers. As the communications market continues to develop, it will have specialized demands which will be filled by firms offering various degrees and types of service. Success will depend on the price structure, services offered and consumer demand.

2. Impact of Deregulation

Deregulation has resulted in numerous changes within the telecommunications industry. A consequence of the restructuring has, ironically, been the expansion of regulatory forces. Two examples are:

a. The scope of federal activity has been reduced after deregulation, but the power they wield in the remaining areas has significantly increased [Ref. 104]. This is a result of an attempt to influence the effects of breakup and encourage further deregulation of the communications industry.

b. With the continuing decrease in the scope of Federal control, each state will be able to exert increasing influence over the design, standards and level of service found within their jurisdiction [Ref. 105]. These variations in systems requirements have the potential to increase the present rate of equipment diversification. Of note, responsive treatment from State regulations is one of the stated reasons for the high profits achieved by the seven Bell holding companies. [Ref. 106]

Following deregulation, a federal court order charged Bell Communication Research Inc. (Bellcore) with the overseeing during a national emergency of the 22 divested Bell operating companies (BOCs). Each BOC is responsible for the partial funding and sharing of technical information with Bellcore. The ability of Bellcore to maintain the expertise necessary to oversee 22 independent and diverging companies during an emergency has yet to be proven [Ref. 107].

3. Emergence of Competition

The demand for digital capability reflects a mostly unsatisfied desire for greater reliability and speed in the transmission of computer messages [Ref. 108]. This demand

has been affected by the increased use of distributed systems wherein geographically separate terminals are linked by communications lines. AT&T had underestimated this demand and was slow in converting its long-distance lines to digital capability [Ref. 109]. Their reluctance to convert was partially due to the large capital investment in existing analog equipment. Smaller, independent firms which were building from scratch had fewer obstacles for implementing all-digital systems. This disparity provides a significant advantage to the smaller competitors.

To compete in the growing telecommunications market, companies are beginning to specialize their services. Attempts are made to attract a customer base with unique requirements by providing additional benefits in one of the following six selection factors [Ref. 110]:

a. traffic volume,

b. transmission rate desired,

c. acceptability of transmission access delays,

d. security capability,

e. flexibility in capabilities and expansion,

f. cost.

The following are a few examples of firms catering to a limited market.

MCI Communication Corp. [Ref. 11] has plans to install over 18,000 miles of fiber-optic cable for digital communication by the end of 1988. This network is estimated to cost

more than $5 billion. About 600 miles of the network is currently operational and connects New York to Washington D.C. MCI is also using two-way, cable TV lines [Ref. 112] in cities such as Atlanta and Omaha to send calls via an MCI switching center. Plans are to expand the system, called Digital Termination Service (DTA), to incorporate 46 cities.

Southern New England Telephone Co. and CSX Corp. joined efforts to construct a 5,000 mile network which will cover 24 eastern states. The project, called LIGHTNET, is already being tested between Jacksonville, Miami and Tampa. Plans are being considered to expand the original 5,000 miles to 8,000. The final system will be joined with a planned system by United Telecom Communications Inc., a unit of United Telecommunications Inc., to create a 23,000 mile nationwide fiber-optic system [Ref. 113].

Two railroads, Norfolk Southern Corp. and Santa Fe Southern Pacific Corp., have joined efforts to develop a project called FIBERTRAK. The system consists of an 8,129-mile fiber optic system running from coast to coast. Completion is expected by the end of 1987 [Ref. 114].

The cable TV companies, which are becoming well established throughout the United States, are apt to become a new challenge as they may decide to amortize their huge investments by offering telecommunications services over their established networks.

4. Bypass--Corporate Reaction to Slow Conversion

Computer, graphic or video data is seldom transferred between users which do not have any organizational ties [Ref. 115]. This restriction is usually the result of both the user's desire and a lack of equipment compatibility. Additionally, data transmission procedures and protocols are generally user and manufacturer specific which inhibits transfer between incompatible machines. These factors tend to create a closed loop of common users operating within a corporate environment which is compatible to the use of dedicated circuits. This environment has motivated 60 to 70% of 'data users' to operate a privately owned branch exchange (PBX) [Ref. 116].

Numerous opportunities exist to obtain a PBX system. Some large companies are finding it cheaper to buy or build their own inter-office phone system for less than the high rates they are paying local phone companies [Ref. 117]. This attractiveness is based on the relative low cost of new technology combined with the tax advantages gained by depreciating their own equipment. These systems can be interlinked between buildings by private microwave towers and distributed within buildings by the use of common cable TV lines leased from local cable companies. As an example of a growing trend, Boeing Co., is studying the feasibility of building its own 70,000-line private network in Seattle [Ref. 118]. The decision to create its own system will deprive the regional phone company of millions of dollars in annual revenue. This

loss may result in higher usage costs for the customers unable to obtain their own internal systems.

Eastern Management Group, a New Jersey market researcher, predicted that 31% of the 500 largest U.S. corporations are using some form of bypass and that another 13% are expected to follow by 1987 [Ref. 117]. New York Telephone estimates that it lost almost $200 million last year due to the bypassing of its services, and threaten that, as a result of this bypass, residential phone rates will rise significantly [Ref. 120]. Some studies indicate that local companies could lose as much as half of their total revenues with the loss of 4% to 6% of their heaviest users [Ref. 121]. Other estimates predict less severe consequences, but also indicate the degree of the problem.

C. INFLUENCE OF INTERNATIONAL POLICIES

1. Size of the Market

Telecommunications has become critical o the world economy. According to the International Telecommunications Union, the investment in communications equipment by such countries as the U.S., France and Japan represent as much as 9% of their total gross domestic product [Ref. 122].

2. Competition in Equipment Sales

The stakes in the global battle over the sale of equipment is enormous. Mr. Edgar A. Grabhorn, managing director of Arthur D. Little Inc.'s world telecommunications information program, estimates that nearly $59 billion was

spent in 1984 on communications equipment. By 1988, he predicts, the annual market will grow by 50% to sales of over $88.4 billion [Ref. 123]. The majority of the equipment sales will center on switching equipment, cable and related network gear. Tremendous competition will exist between various countries for a share of the sales.

Deregulation has opened the American market. While U.S. suppliers such as GTE, MCI Communications, and Rolm have responded with new products, there has been increased sales from foreign corporations such as Britain's Plessey-West Germany's Siemens and Japan's NEC. Faced with this new competition at home, many American firms are looking for a greater share of the international market which is growing at 1% annually versus a 10% domestic increase [Ref. 124].

As different countries establish unique technical standards, communications equipment becomes more specialized for use in a particular country. In addition, certain countries, such as France, require that a fixed percentage of telecommunications components be manufactured within their country's industrial base [Ref. 125]. This tends to enhance international compatibility problems.

Overseas competitors are rapidly joining with American manufacturers in order to meet two main objectives. First, to gain access to the new technology such as digital equipment manufacturing, and secondly to quickly gain additional marketing strength in the extremely competitive U.S. market [Ref. 126].

3. Competition in PABX Sales

As foreign government-owned telephone agencies are reluctant to purchase equipment from suppliers outside of their own country, international manufacturers are stressing the sale of equipment directly to the user. This has become particularly evident in the U.S. since the Federal Communications Commission ruled in 1968 that non-telephone company equipment could be hooked up to the public telephone network. This new competitiveness in the sale of PABXs (Private Automatic Branch Exchanges) and local area systems has encouraged foreign manufacturers to enter into this rapidly expanding market [Ref. 127].

4. Foreign Deregulation

The United States has become one of the few countries which allows private ownership of public utilities. While the trend is increasing in certain countries such as England and Japan, governmental control is the general rule in the majority of the world.

Foreign market places are not immune to the desire for the services offered by newer technology. Consumer demand becomes more pronounced as users become aware of services and cost structures available in other countries. Many of the European countries do not offer even the basic services which U.S. consumers take for granted As an example, in most of Europe it is impossible to obtain an itemized telephone bill. Users receive a lump-sum bill which is impossible

to investigate for correctness. To make matters worse, service in most European countries and Japan are signficantly more expensive than that offered in the United States [Ref. 128].

Corporate management tends to centralize their international corporations in locations where the completion of corporate goals can be done with the greatest degree of efficiency. With the rising need for inexpensive and efficient communications, multinationals are placing increased importance on telecommunication utility services in weighing their decisions as to where they locate their foreign offices. This factor will place pressure on foreign countries to develop reliable, varied and inexpensive communications services [Ref. 129].

Many European countries have created a domestic industry to provide their own communication equipment. For example, in Sweden communications account for 3% of the manufacturing employment. A protected market has allowed many of these firms to become less competitive than they normally would be. With the introduction of marketplace forces, these companies would be more inclined to upgrade equipment and expand services [Ref. 130].

While regulations and political practices vary greatly between countries, each marketplace has some means of responding to user demands. In several countries, public networks are relying on technological progress to aid them

in maintaining their monopolies by increasing user satisfaction. Other alternatives available to foreign governments include a gradual shift toward deregulation which is evidenced in such countries as the United States, England and Japan. The deregulation option results in complicated political issues for almost every government. In the majority of cases, government-operated utilities are strongly unionized, and attempts to make them competitive invite violent reaction from hordes of civil servants. Additionally, the public utilities usually contribute substantial revenues to the government purse [Ref. 131].

D. FUTURE TELECOMMUNICATIONS TRENDS

1. Factors Influencing Change

Technological advancements and deregulation have influenced the environment in which both the providers and users of services must adapt. The following are eight factors which are expected to have significant influence over the foreseeable future:

a. Marketplace forces are causing changes in price structures and capabilities.

   1. User demand for a variety of services is encouraging the rapid expansion of communication capabilities [Ref. 132]. Corporate information is becoming more commonly treated as a valuable resource and greater emphasis is being placed upon its efficient processing. Service alternatives are being critically reviewed by phone companies as a method to increase marketability. [Ref. 133]

   2. A greater number of manufacturers are developing communications equipment which has resulted in

tremendous competition [Ref. 134]. This fragmented market has encouraged many companies to seek a wider customer base for their product [Ref. 135]. Strategies have included the expansion of digital utilization into small population centers, the offering of more diverse service options and the lowering of service charges.

b. Deregulation has encouraged competition and increased flexibility. The following are examples of areas affected by deregulation:

1. The categorization of regulations by video (TV), voice (radio) and data (telegraph) has become less precise. Merging technologies and capabilities has resulted in a common grouping entitled "information handling." The reduction of regulation variances and protectionism will result in a merging of services and the demise of less efficient means of transmission. [Ref. 136]

2. Divestiture has brought about millions of dollars in cost savings by opening up competition among vendors. Regional companies are freed from having to buy the majority of their equipment from AT&T and are not actively shopping around for equipment. Benefits are achieved as a result of the increased incentives for the timely introduction of new technologies and services. Problems arise from equipment diversification which is encouraged by increased specialization and decentralized State regulation. [Ref. 137]

3. The impact on consumers is varied. Benefits will include a decrease in long-distance rates and easier access to discount carriers [Ref. 138]. Disadvantages include higher residential phone rates, equipment costs and service charges. [Ref. 139]

4. Greater competition is achieved by creating an increase in equality of opportunity. Initially this entails placing rate restrictions on AT&T to encourage the development of smaller competitors [Ref. 140]. Problems occur if these new companies desire easy profits instead of creating long-term commitments.

5. The attachment of equipment from other manufacturers to public network lines was realized after a bitter legal fight ending in 1968 [Ref. 151]. This has

isolate and complete repairs. The degree of training for digital systems is reduced by modularity and diagnostic tools.

(2) The survivability of nodes is enhanced by the tendency to build smaller and more decentralized control centers. This trend is feasible as the result of digital technologies' ability to create smaller, more energy-efficient equipment with a lower maintenance requirement.

(3) The increased usage of microwave transmitters, especially over rugged routes, has enhanced the survivability of links by shortening the distance necessary for repair personnel to travel.

(4) The feasibility of maintaining a pool of both spare parts and entire systems is improved due to the reduced cost, size and power requirements of digital components. For example, Northern Telecom's Federal Systems and SL-100 divisions have developed a transportable digital communications system. The system is contained within two trailers, and can act simultaneously as both a PBX and a tandem switch. The SL-100 Transportable can independently provide emergency communications, in the event of a natural disaster, within a few hours after linking to the surviving network [Ref. 166].

b. Personnel and Equipment Resources for Timely Repairs

(1) While special requirements were previously built into the local hardware, modern digital equipment

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The completion of goals, as set by the Nationwide Emergency Telecommunications System (NETS), is dependent upon the technical environment in which the system must operate. This environment is being affected by the rapid rate of change in the implementation of technically advanced equipment. Varying capabilities have had an impact on the services available to customers, cost structure, switching capabilities, reliability, quality assurances and security controls. The resulting long-term effects must be understood to determine the future environment in which NETS will operate.

The following conclusions are based upon a comparison of NETS' capability requirements, as listed in Chapter I, and environmental factors created by digital/analog conversion.

1. Survivability

a. Survivable System of Nodes and Links

(1) The degree of survivability in a digital system is usually higher than that attained in a similar analog system due to the level of security provided by the system architecture and the extent of defensive programming within the software. Additionally, a better monitoring and alarm system is provided to ensure early detection and provide adequate information on suspected problems. A well-trained operating and maintenance staff is then required to

4. wider bandwidth availability, and

5. size, power and efficiency requirements.

NETS' objectives tend to place greater emphasis on:

1. timeliness of conversion from Analog to Digital,

2. compatibility with equipment which may be connected during reconstruction,

3. survivability requirements, and

4. security from interception, manipulation or jamming.

To more closely align divergent views, government incentives may be desirable. They could consist of financial incentives, tax breaks or enforced regulations.

Data processing promises to consume enormous quantities of bandwidth if it can be made available cheaply enough [Ref. 164]. Even at current prices, a grave shortage of channel bandwidth is predicted in the near future resulting in higher capacity cables being connected to homes and businesses. The use of fiber optics in long-distance communications is expanded.

Increased utilization of cable TV network as a means of interconnecting networks and providing home access to data bases. This will allow an increasing amount of white-collar work to be accomplished in the home.

d. The Year 2000

It is estimated that the telecommunications network will be all-digital by the year 2000. (All-digital is defined as being more than 95% digital. It will probably be less expensive for networks of minimal size to remain analog [Ref. 165].)

E. CHAPTER SUMMARY

Civilian corporations are reacting to the changing perspective of costs and benefits in a manner which maximizes cost during a peacetime environment. Several predicted results parallel NETS' objectives. Areas of commonality include a general desire for:

1. digital transmission/switching,
2. packet switching,
3. adaptive routing,

Greater demand for digital transmission capability leads to an increased level of broadband data transmission over public, private switched and leased point-to-point lines. User demand encourages the timely expansion of broadband capability [Ref. 160].

The increased usage of time-division multiplexing on digital links provides the capacity for a greater number of data channels on existing lines.

c. 1990s

AT&T said it will spend more than $2 billion between 1985 to 1990 to expand its long-distance network to carry data, television signals and regular telephone calls. The company said 35% to 40% of its network will use digital technology by 1990, including undersea cables to Europe and Japan being built with international partners. In addition, AT&T said it will build a 9,000-mile microwave system that uses radio signals to send signals in digital form, and will also have 21,000 miles of fiber-optic cable in place [Ref. 161].

By 1990, AT&T's share of the long-distance market could slip as low as 60%, although its revenues should increase as the market grows [Ref. 162].

A doubling of residential rates is expected by 1990 as an attempt to more closely match the price of a service with its actual cost. Previous subsidies for local service rates will be reduced to increase competitiveness with companies concentrating only on high-profit areas [Ref. 163].

cable TV carriers and local phone companies. The cable network system becomes an inexpensive means of interconnecting privately owned networks.

Telecommunications will play a role in the increasingly decentralized processing environment of the future. A tendency for centralized control of corporate data base will continue, but data entry and retrieval will become more available to actual work sites. This allows for documents to be produced only when and where actually required and thereby eliminating many of the intermediary steps which previously consumed so much time and effort.

Electronic mail becomes more popular, and privately owned systems are developing in highly industrialized areas such as New York City. The electronic transfer of funds, payment of bills and placement of orders becomes more common but is still in its infancy.

Use of the Touchtone telephone as a computer terminal spreads. Attachments to the telephone for various commercial uses are made possible by increased digital transmission capability. Possible uses include the transmission of information contained on magnetic strips placed on credit cards.

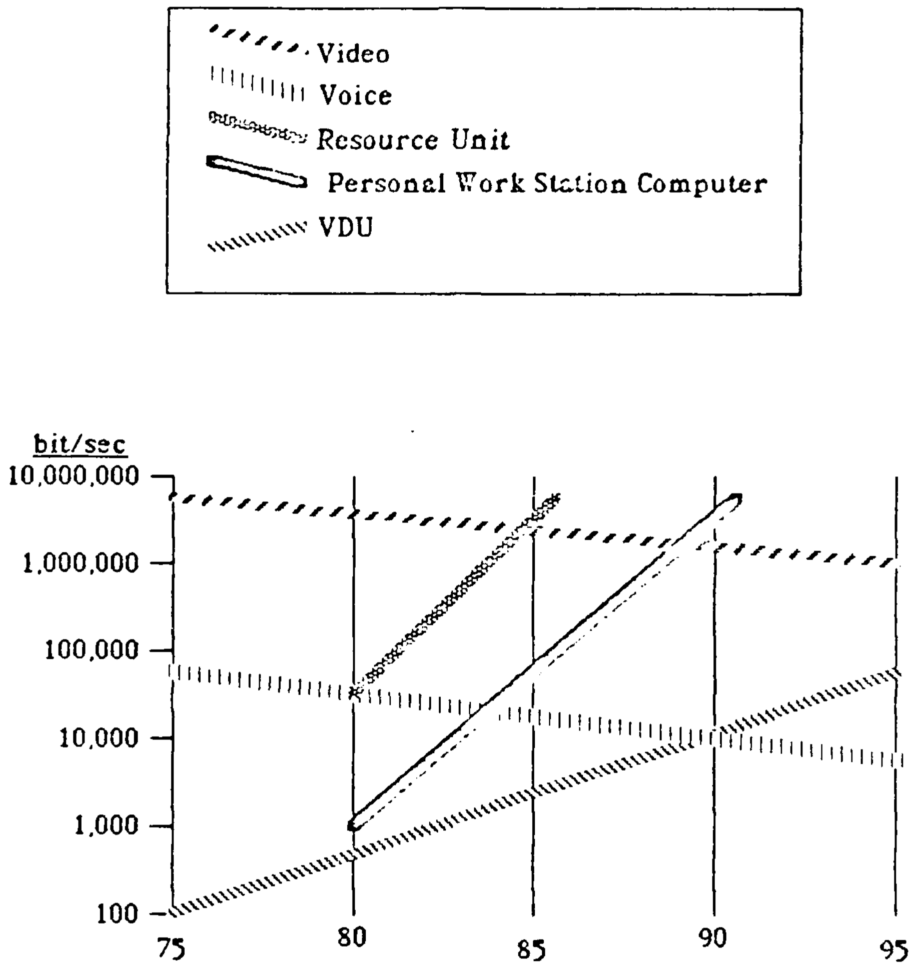
Refined technology such as "large-scale integration" lead to a new generation of digital equipment which increases flexibility, capacity and cost savings.

Automatic least-cost routing will become more of a reality as the percentage of digital switches increases. Stored Program Control (SPC) will allow for this flexibility by using software especially designed for real time switching.

AT&T's share of the long distance market will drop as a result of the policy of "equal access." Customers will be able to enter discount carrier systems with the addition of just one digit to the number being called. Charleston, W. Va. was the first city to use equal access and provides an example of the potential impact on AT&T. Initial results indicated that MCI grabbed 15% of the market and GTE Sprint Communications Corp. took 6% [Ref. 159]. AT&T is expected to minimize its predicted loss by introducing equal access on a local basis over a varied timetable. This will increase advertising costs for the discount carriers and hopefully reduce the number of customers who switch services.

Computerized private branch exchanges are becoming more popular with large corporations. Prices will continue to drop due to global competition. Total charges for interconnecting lines will drop as fewer are required due to the increased usage of multiplexors and concentrators. These units have become more efficient as digital switching and transmission equipment become more common.

Additional uses for cable TV are found popular as federal regulations allow greater competition between



[Ref. 156]

Figure 8.2 An Illustration of the Increased Bandwidth Requirements Through 1995

percentage is increasing as users take advantage of the special features offered by digital technology such as increased efficiency in networking and interactive applications. The percentage of digital data transmission may well approach 25 to 30% in the next 20 years [Ref. 155].

Figure 8.2 reflects predicted changes in the future demand for bandwidth capacity.

4. General Forecast of the Future

Unless specifically referenced, predictions are the conjecture of the author.

a. Remainder of 1985

An increase in competition will continue. More discount carriers will drop their monthly subscription fees and run promotionals to increase their share of the market.

AT&T's share of the $40 billion long distance market is predicted to drop by 3% [Ref. 157].

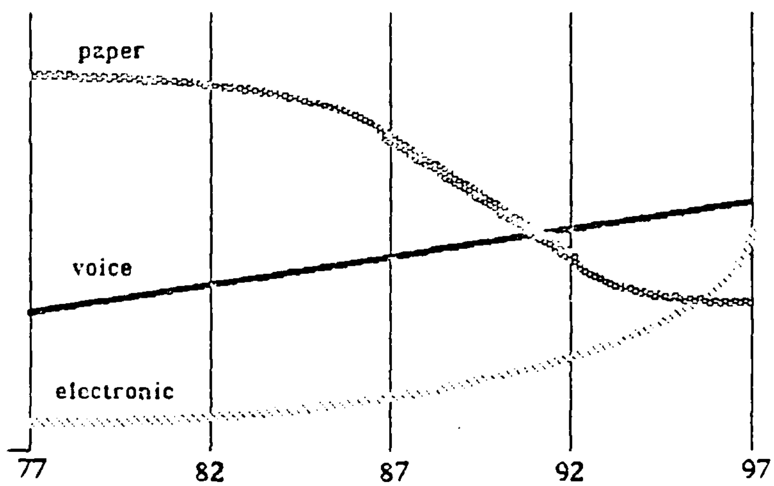
New England Telephone Co., provides an example of the rapid conversion rate of central office switches from analog to digital. The company reports that only 13 of 385 New England Telephone switches were digital on Jan. 1, 1984, but by the end of 1985 the number will have increased to 56 [Ref. 158].

b. Second Half of the 1980s

The number of service companies targeted to the same customer base will tend to decrease as less efficient firms are forced out of the market.

3. Predictions Concerning the Future Demand for Telecommunications Services

There is the potential for many firms to increase their competitive position by taking greater advantage of information services. Newer technology will encourage the growth of electronic display, facsimile, graphics and video. Corporations will find the transmitting of data between sites to be cheaper and less prone to distortion. This will result in an increase in the demand for varied services and increased capabilities. To demonstrate, Figure 8.1 reflects predicted demand for three types of office media.



[Ref. 154]

Figure 8.1 The Relationship of Three Types of Office Media from 1977 through 1997

It is estimated that between 5 to 10% of the traffic going over the telephone network is digital data. This

With digital systems, information can be multiplexed and transmitted over telephone cable, coaxial cable, microwave, or almost any media that can transmit quantized signals. New areas being studied include microwave radio, satellites, and optical fiber cables. These techniques promise to increase the capacity and quality of transmitting information over long distances. In addition, microwave radio and fiber cables are becoming a more popular means of linking privately owned networks.

Cable TV networks promise to become future competitors within the telecommunication industry. Enough excess channel capacity exists to handle the initial demands of transmitting voice or computer data between several privately owned networks. Advantages include the broad bandwidth of cable lines and the extensive network already in place. Agreements with telephone companies are the inhibiting factor. During implementation and expansion, cable TV companies needed space on the telephone poles owned by the phone companies. Additionally, many of them purchased or leased their equipment from the local telephone company. Negotiated contracts frequently contained clauses which prevented the cable TV carriers from engaging in two-way communications. This restriction effectively ruled out many of the more profitable applications. The FCC is presently reviewing regulations which are intended to remove some of the restrictions placed on cable TV carriers.

The transition to digital equipment began later for the Regional Bell Operating Companies (RBOCs) than for the independents [Ref. 151]. After a late start, RBOC progress has been substantial. Before the decade ends, digital switches will be in place for every key location for both RBOCs and independents [Ref. 152]. Table III indicates the estimated percentage of digital equipment between 1983 and 1986 for independents, RBOCs and the total industry.

TABLE III

RBOCS AND INDEPENDENTS: DIGITAL TRANSITION 1983-1986

ACCESS LINES

	Top 5 Independents	RBOCs	Total Industry
1983	14%	0%	3%
1984	24%	4%	7%
1985	37%	13%	16%
1986	48%	22%	26%

CENTRAL OFFICE SWITCHES

	Top 5 Independents (Hosts & Remotes)	RBOCs (Host switches only)
1983	18%	3%
1984	20%	7%
1985	29%	13%
1986	37%	24%

[Ref. 153]

g. A dramatic increase in the cost of research, development and marketing has been experienced. Digital equipment, with its related software, is more expensive to design than the previously used analog equipment. Subsequently a greater proportion of a company's assets must be obligated over a longer time span. Firms must either acccept a greater development risk or split the effort with other firms. [Ref. 149]

h. The development and manufacturing of telecommunications equipment is becoming more globally oriented which has created a greater potential for incompatibility between systems.

2. Predictions Concerning Future Telecommunications Capabilities

The telecommunications industry is expending enormous resources to expand and modernize their equipment to meet future demand. Table II reflects this increasing trend in construction expenditures.

TABLE II

U.S. CARRIER CONSTRUCTION EXPENDITURES
($ millions)

	RBOCs*	Independents	Interexchange Carriers	Total
1981	13,502	5,091	1,700	20,293
1982	13,613	4,986	2,000	20,599
1983	12,506	5,128	2,600	20,234
1984	13,053	4,954	3,720	21,727
1985	14,177	5,439	4,018	23,634
1986	14,287	5,738	4,080	24,105

*RBOCs (Regional Bell Operating Companies) construction budgets are adjusted to reflect divestiture.

[Ref. 150]

created tremendous competition in the marketing of private networks for medium and large corporations.

c. Increased efforts at worldwide standardization. The successful integration of networks requires standards to ensure the proper interfacing of transmission protocols [Ref. 142]. In North America, standards are essentially set by the Bell System as they currently service over 80% of the telephone network [Ref. 143]. The majority of the rest of the world relies on two international committees established under the International Telecommunication Union (ITU). The groups are the International Telegraph and Telephone Consultative Committee (CCITT) and the International Radio Consultative Committee (CCIR). The standards of the Bell System and CCITT are not always compatible. Manufacturers of communications equipment often try to implement the recommendations of both groups when they do not conflict or create excessive cost requirements. [Ref. 144]

d. The functions of voice and data transmission are being combined. This union of capabilities allows for the reduction of overall equipment and support costs while offering uniform operations. [Ref. 145]

e. The requirement for increased reliability and speed in the transmission of computer data is being researched. In the near term, increased usage of fiber optics and digital repeaters are expected to result in acceptable standards. [Ref. 146]

f. The telecommunications world is in a rapid state of change. Equipment which had previously experienced a useful life span of up to 30 years is now becoming obsolete almost as fast as it is installed [Ref. 147]. This requirement for large capital expenditures promises to raise the future costs of communication services. It remains to be seen how these costs will be distributed among consumers. The emphasis will be placed upon offering unique service options to increase competitiveness with similar firms. These unique features will hopefully attract larger corporate accounts which promise to generate greater revenues with minimal installation costs. Necessary development costs may be subsidized by increasing standard fees while minimizing charges for specialized services to larger customers [Ref. 148]. This is the opposite of what has traditionally been followed in the United States because of government regulations.

addresses operational flexibility through its software. This allows for a high degree of regional similarity in hardware.

(2) Digital equipment offers hardware modularity and software diagnostics tools. As local repairs usually entail the replacement of circuit boards, adequate replacements can be retained for timely repairs with minimum of expertise.

c. Minimize Transmission Distortion Created by Electromagnetic Interference

(1) Radiation resistance is crucial for hardening electronic equipment against the electromagnetic pulse (EMP) created by a nuclear blast. Digital equipment is especially vulnerable to EMP as it operates with extremely low voltages. The power surge can disrupt messages in transit or burn out sensitive components.

(2) Research is rapidly progressing on developing the techniques necessary to commercially substitute gallium arsenide (GaAs) for the silicon normally used in manufacturing microelectronic chips. The military is especially interested as GaAs promises to not only significantly increase processing speed but will vastly improve radiation resistance. GaAs can withstand 10^7 to 10^8 rads while silicon can only endure 10^3 to 10^4 rads [Ref. 167]. Another advantage of gallium arsenide over silicon is its greater insulation properties. This helps to isolate circuit paths on the chip thereby allowing for greater miniaturization. This property, along with the increased resistance to

radiation, has spawned the idea of creating an integrated repeater. The repeater would combine a miniature laser (GaAs is ideal for light generation), amplifier and digital processor all on the same chip. Such a device would prove vital in decreasing the size and cost of fiber optic connections. A natural side benefit would be the increased resistance to electromagnetic pulses [Ref. 168].

(3) When digital transmission is combined with fiber optics, another degree of resistance to distortion is attained. The fiber optic <u>cable</u> is immune to electromagnetic interference [Ref. 169].

d. Maintain Adequate Physical Security:

By decentralizing the location of vital operational resources the vulnerability of the system to central nodes is reduced. The infliction of physical disruption would have to occur at numerous nodes before a significant degradation would be incurred.

2. Operational Flexibility

a. Quickly Accessible During An Emergency

Digital switching increases the number of available entry ports which allows for more efficient and timely recognition of priority calls. Conversely, digital's requirement for a greater bandwidth decreases the availability of long-distance lines on a comparable basis with analog systems. This may increase the qualifying priority for entry to long-distance trunks.

b. High User Demands Can Be Controlled On A Prioirty Basis

(1) Electronic switching, in conjunction with stored program control (SPC), allows for the addition, modification and monitoring of function and control sequences. These instruction sequences are designed to create automatic routing wherein damaged links are avoided and optimal paths are chosen. This dynamic routing can place limits on the size of queues waiting for each individual link or hold certain links open awaiting calls with a prespecified priority level.

(2) A related problem is the tendency by users to keep certain lines open to insure the ability for future communication needs. Packet switching assists in partially addressing this problem. Packetization allows for high priority messages to get through a 'link' without having to wait for the completion of longer messages. In addition, certain control sequences can be added to these messages which would modify queueing lengths or priority levels for acceptance to the queue.

c. Provide Service to Geographically Separate Users

The implementation of digital technology to the longer trunk lines has been limited by the need for wider bandwidths. With current long-distance transmission methods, analog systems prove more profitable with their smaller bandwidth requirements. As greater use of fiber optics is

experience, digital transmissions will become more common over the longer trunk lines.

d. Reroute Messages in Response to Damaged Links

(1) While telephone lines cannot be effectively monitored by traditional analog methods, digital systems have the capability of carefully monitoring various performance parameters [Ref. 170]. Whenever a fault occurs, an alarm is activated at a central maintenance site.

(2) The ability to route dynamically is one of the major benefits of packet switching wherein routing routines respond to the success or failure of network probes. Each network node examines the destination address of incoming packets to compare with local address tables. The tables are modified according to routing criteria which are routinely updated to reflect both the operational status and the size of queues at each node.

e. Responsive to Distributed Controls with Centralized Policy and Guidance

(1) Distributed controls are usually more desirable than having them locked into a central computer. Distribution assists in inhibiting a control problem in one area from expanding into other areas. The major advantage is that, given by any two nodes that are connected after a disaster, a message can be sent. A disadvantage comes from the lack of global information which may result in a nonoptimal path selection.

(2) To ensure uniformity of standards, distributed controls must be based upon centralized policy and guidance. This is made possible by the flexibility of digital software and the ability to easily transmit control signals over digital transmission lines.

f. Handle a Variety of Information

Digital communications, due to its discrete nature, is adaptable to the transmission of almost all types of data. This includes the sending of computer data, graphics, voice or machine instructions.

g. Maintain Adequate Security Against Unauthorized Entry

(1) A distributed system is vulnerable to entry from any point on the interconnecting lines. If the intruder's intent is to disrupt the lines, then physical security and adaptive routing are potential countermeasures. If the intent is to attain a transmission surveillance capability then a means of effective encryption is needed.

(2) The basic technical problem with encryption is to achieve an acceptable level of speech quality, in a cost effective manner, with terminal equipment (voice processors, cryptographic equipment and modems) meeting environmental constraints. Digital voice processing can be accomplished by a variety of techniques with digitization rates varying from below 2.4 to above 50 kbits/sec [Ref. 171]. The use of a higher digitization rate increases the cost of transmission but reduces the quality of the voice transmission. The

Defense Communications System (DCS) plans to use a terminal similar to one under development for civilian use. Its primary digitization rate will be 9.6 kbits/sec and use adaptive predictive coding (APC) [Ref. 172]. A secondary rate of 2.4 kbits per second will use a processor identical to that used for narrow-band tactical communications. The 2.4 rate produces speech which is understandable but somewhat artificial. Modems for both rates are included in the terminal. The 2.4 digitization rate will be the most survivable element of the system as it can use almost all communications media even under degraded conditions [Ref. 173].

B. RECOMMENDATIONS

1. A continued study of the changing communications environment is required. Advancements in technology are resulting in the creation of complicated systems which are difficult to maintain and control. In the event of extensive damage, advanced planning, equipment reserves, trained personnel and established standards will be required to rebuild and maintain a communications system.

2. Congress must choose between the conflicting NETS' requirements of responsiveness, survivability or the simultaneous achievement of both goals. Improvement in both areas is desirable, but cannot be achieved with the same set of investments. The amount of required funding, necessary equipment modifications and effect upon the peacetime communications industry varies with each alternative chosen.

3. The rate of transition from analog to digital should be encouraged through various legislative means.

4. Incentives should be adopted to encourage the use of packet switching, adaptive routing and defensive programming.

5. Reserve digital switching equipment, repeaters and cable should be stored at local sites to replace damaged equipment during a national emergency.

6. Measures are required to minimize the impact of complicated protocol interfaces. Either government regulations should be designed to create an environment conducive to creating common standards or a central data base on system variances should be maintained by the Bell Communications Research Inc. (Bellcore).

7. The introduction of unauthorized messages must be controlled by enforced encryption and verification analysis. (The digital process allows for verification analysis by the modification of existing message headers.)

8. The commandeering of commercial trunk lines to provide a dedicated military net could be minimized by increasing the availability of resources to the Minimum Essential Emergency Communications Netowrk (MEECN).

LIST OF REFERENCES

1. Desmond Ball, Can Nuclear War Be Controlled? (Adelphi Papers, No. 169, Autumn 1981), p. 5.

2. Ibid.

3. Ibid.

4. Ibid., p. 3.

5. Congressional Budget Office (CBO), Study on Strategic Command, Control, and Communications: Alternative Approaches for Modernization (CBO, October 1981), p. 7.

6. Ibid., p. ix.

7. Ibid., p. 3.

8. House Committee on International Relations, Report on The First Use of Nuclear Weapons: Preserving Responsible Control (March 1976), p. 93.

9. Desmond Ball, Can Nuclear War Be Controlled? (Adelphi Papers, No. 169, Autumn 1981), p. 9.

10. Congressional Budget Office (CBO), Study on Strategic Command, Control, and Communications: Alternative Approaches for Modernization (CBO, October 1981), p. 4.

11. Desmond Ball, Can Nuclear War Be Controlled? (Adelphi Papers, No. 169, Autumn 1981), p. 3.

12. Ibid., p. 4.

13. Ibid.

14. Lecture by Professor Jack LaPatra, Naval Postgraduate School, Monterey, Ca., 8 July 1984.

15. Congressional Budget Office (CBO), Study on Strategic Command, Control, and Communications: Alternative Approaches for Modernization (CBO, October 1981), p. 4.

16. Ibid.

17. Ibid.

18. Ibid.

19. Lecture by Professor Jack LaPatra, Naval Postgraduate School, Monterey, Ca., 8 July 1984.

20. Ibid.

21. Ibid.

22. Ibid.

23. Ibid.

24. Congressional Budget Office (CBO), Study on Strategic Command, Control, and Communications: Alternative Approaches for Modernization (CBO, October 1981), p. 36.

25. L. Ackzell and F. Bigi, "The Transition from Analogue to Digital Telecommunication Networks: The GAS 9 Approach," Telecommunication Journal, September 1984, pp. 513-518.

26. Leonard Lewin, Telecommunications in the U.S. Trends and Policies (Artech, 1982), p. 289.

27. William R. Doerner, "Is It Safe to Use the Phone?," Time, October 29, 1984, p. 38.

28. Graham Langley, "Modern Switching Means Digital Switching," Telephony, 9 July 1984, p. 42.

29. Ibid.

30. Ibid., p. 46.

31. George R. Trimble, Jr., Digital PABX Functions, Features & Applications (Carnegie Press, Inc., 1983), p 2-24.

32. "Sparks Are Flying Among Telephone Switchmakers," Special Report, Business Week, 24 October 1983, p. 144.

33. R.P. Lippman, Survivable Routing Procedures for Circuit-Switched Satellite-Terrestrial Networks, IEEE 1983 International Communications Conference, Vol. 1, p. A1.3.1.

34. Ibid.

35. Ibid.

36. Ibid., p. A1.3.4.

37. Ibid.

38. Ibid.

39. Ibid. p. Al.3.5.

40. James Martin, Future Developments in Telecommunications (Prentice-Hall Inc., 1971), p. 69.

41. George R. Trimble Jr., Digital PABX: Functions, Features & Applications (Carnegie Press, Inc., 1983), p. 1-7.

42. Ibid., p. 3-27.

43. Roger L. Freeman, Telecommunication System Engineering: Analog and Digital Network Design (John Wiley & Sons, Inc., 1980), p. 383.

44. Raymond T. Moore, Norman F. Greer and Henry A. Graf, "Gridnet: An Alternative Large Distributed Network," Computer, April 1984, p. 57.

45. John Wilke, "Surprise! Ma Bell's Babies are Stealing the Show," Business Week, 3 December 1984, p. 104.

46. Gerhard Merz and Gerhard Pumpe, "Economical Implementation of Dedicated Data Circuits in Public Telecommunications Networks: A Comparison of the Analog and Digital Approaches," Telecommunication Journal, October 1984, p. 552.

47. Ibid.

48. Leonard Lewin, Telecommunications in the U.S.: Trends and Policies (Axtech, 1982), p. 289.

49. John Bellamy, Digital Telephony (John Wiley & Sons, 1982), p. 3.

50. Ibid.

51. Arnold M. CcCalmont, "Comparisons of Analog and Digital Speech Encoding," Military Electronics Defence Expo '80 (Interavia S.A., October 1980), p. 3.

52. L. Ackzell and F. Bigi, "The Transition form Analogue to Digital Telecommunication Netowrks: The GAS 9 Approach," Telecommunication Journal, September 1984, pp. 513-518.

53. Helmut Lukas, Rick Neumann and Grant Pacey, "Splicing Single Mode Optical Fiber," Telephony, 21 January 1985, p. 45.

54. Gerhard Merz and Gerhard Pumpe, "Economical Implementation of Dedicated Data Circuits in Public Telecommunications Networks: A Comparison of the Analog and Digital Approaches," Telecommunication Journal, October 1984, p. 554.

55. Roger L. Freeman, Telecommunication System Engineering: Analog and Digital Network Design (John Wiley & Sons, Inc., 1980), p. 384.

56. Ibid., p. 384.

57. Ibid., p. 377.

58. L. Ackzell and F. Bigi, "The Transition from Analogue to Digital Telecommunication Networks: The GAS 9 Approach," Telecommunication Journal, September 1984, pp. 513-518.

59. Graham Langley, "Modern Switching Means Digital Switching," Telephony, 9 July 1984, p. 38.

60. L. Ackzell and F. Bigi, "The Transition from Analogue to Digital Telecommunication Netowrks: The GAS 9 Approach," Telecommunication Journal, September 1984, p. 514.

61. Arnold M. CcCalmont, "Comparisons of Analog and Digital Speech Encoding," Military Electronics Defence Exp '80 (Interavia S.A., October 1980), p. 3.

62. George R. Trimble, Jr., Digital PABX Functions, Features & Applications (Carnegie Press, Inc., 1983), p. 3-2.

63. Roger L. Freeman, Telecommunication System Engineering: Analog and Digital Network Design (John Wiley & Sons, Inc., 1980), p. 376.

64. Gerhard Merz and Gerhard Pumpe, "Economical Implementation of Dedicated Data Circuits in Public Telecommunications Networks: A Comparison of the Analog and Digital Approaches," Telecommunication Journal, October 1984, p. 556.

65. Ibid., p. 552.

66. L. Ackzell and F. Bigi, "The Transition from Analogue to Digital Telecommunication Networks: The GAS 9 Approach," Telecommunication Journal, September 1984, p. 514.

67. Roger L. Freeman, Telecommunication System Engineering: Analog and Digital Network Design (John Wiley & Sons, Inc., 1980), p. 376.

68. F.J. Redmill, "Principles of Telecommunications Switching System Maintenance," *Telecommunication Journal*, January 1984, p. 23.

69. Ibid., p. 28.

70. Ibid., p. 24.

71. Graham Langley, "Modern Switching Means Digital Switching," *Telephony*, 9 July 1984, p. 32.

72. James Martin, *Future Developments in Telecommunications* (Prentice-Hall Inc., 1971), p. 76.

73. Roger L. Freeman, *Telecommunication System Engineering: Analog and Digital Network Design* (John Wiley & Sons, Inc., 1980), p. 112.

74. John Bellamy, *Digital Telephony* (John Wiley & Sons, 1982), pp. 65-66.

75. Edmund B. Fitzgerald, "Maintaining Excellence in an Open Market," *Telephony*, 9 January 1984, p. 28.

76. "Telecommunications: The Global Battle," *Business Week*, 24 October 1983, p. 128.

77. Amos E. Joel, Jr., "Progress Report: North American Installations of Time Division Digital Switchesk," *Telephony*, 9 July 1984, p. 55.

78. Amos E. Joel, Jr., "Electronic Switching: Digital Central Office Systems of the World," *IEEE Trans. Commun.*, Vol. Com-27, July 1979, pp. 948-959.

79. Ibid.

80. Ibid.

81. F.J. Redmill, "Principles of Telecommunications Switching System Maintenance," *Telecommunication Journal*, January 1984, p. 23.

82. Amos E. Joel, Jr., "Progress Report: North American Installations of Time Division Digital Switchesk," *Telephony*, 9 July 1984, p. 55.

83. Roger L. Freeman, *Telecommunication System Engineering: Analog and Digital Network Design* (John Wiley & Sons, Inc., 1980), p. 100.

84. Graham Langley, "Modern Switching Means Digital Switching," *Telephony*, 9 July 1984, p. 32.

85. Gerhard Merz and Gerhard Pumpe, "Economical Implementation of Dedicated Data Circuits in Public Telecommunications Networks: A Comparison of the Analog and Digital Approaches," Telecommunication Journal, October 1984, p. 553.

86. "Boom in Electronic Messages Spurs Demand for Systems Using Fiber-Optic Cable," Wall Street Journal, 9 November 1984, p. 3.

87. George R. Trimble, Jr., Digital PABX: Functions, Features & Applications (Carnegie Press, Inc., 1983), p. 3-1.

88. Ibid., p. 3-6.

89. Leonard Lewin, Telecommunications in the U.S. Trends and Policies (Artech, 1982), p. 289.

90. George R. Trimble, Jr., Digital PABX: Functions, Features & Applications (Carnegie Press, Inc., 1983), p. 2-13.

91. Ibid.

92. Ibid., p. 3-6.

93. Roger L. Freeman, Telecommunication System Engineering: Analog and Digital Network Design (John Wiley & Sons, Inc., 1980), p. 384.

94. "Telecommunications: The Global Battle," Business Week, 24 October 1983, p. 128.

95. L. Ackzell and F. Bigi, "The Transition from Analogue to Digital Telecommunication Networks: The GAS 9 Approach," Telecommunication Journal, September 1984, p. 514.

96. George R. Trimble, Jr., Digital PABX: Functions, Features & Applications (Carnegie Press, Inc., 1983), p. 3-12.

97. L. Ackzell and F. Bigi, "The Transition from Analogue to Digital Telecommunication Networks: The GAS 9 Approach," Telecommunication Journal, September 1984, p. 514.

98. Amos E. Joel, Jr., "Progress Report: North American Installations of Time Division Digital Switchesk," Telephony, 9 July 1984, p. 55.

99. George R. Trimble, Jr., Digital PABX: Functions, Features & Applications (Carnegie Press, Inc., 1983), p. 2-24.

100. John M. Lusa, "Major Industry Study Shows Growing Role for Data Communications," Telecommunication Products Plus Technology, March 1985, p. 17.

101. Ibid.

102. "Communications is Dealing Business a Potent New Hand," Business Week, 24 October 1983, p. 131.

103. Roger L. Freeman, Telecommunication System Engineering: Analog and Digital Network Design (John Wiley & Sons, Inc., 1980), p. 381.

104. Edmund B. Fitzgerald, "Maintaining Excellence in an Open Market," Telephony, 9 January 1984, p. 28.

105. Ibid.

106. Mark D. Maremont, "Did It Make Sense To Break Up AT&T?," Business Week, 3 December 1984, p. 86.

107. "The Disaster Dossier," Datamation, 15 October 1984, p. 53.

108. "Telecommunications: The Global Battle," Business Week, 24 October 1983, p. 127.

109. Del Myers and Czatdana Inan, "Telecommunications Carriers to Spend $23.634 Billion in 1985," Telephony, 14 January 1985, p. 35.

110. Gerhard Merz and Gerhard Pumpe, "Economical Implementation of Dedicated Data Circuits in Public Telecommunications Networks: A Comparison of the Analog and Digital Approaches," Telecommunication Journal, October 1984, p. 552.

111. "Boom in Electronic Messages Spurs Demand for Systems Using Fiber-Optic Cable," Wall Street Journal, 9 November 1984, p. 3.

112. "The Push to 'Bypass' Local Telephone Companies," Business Week, 27 August 1984, pp. 90-91.

113. "Boom in Electronic Messages Spurs Demand for Systems Using Fiber-Optic Cable," Wall Street Journal, 9 November 1984, p. 3.

114. Ibid.

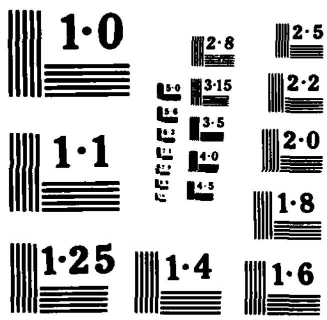
AD-A156 831 AN EVOLVING DIGITAL TELECOMMUNICATIONS INDUSTRY AND ITS IMPACT ON THE OPE..(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA R J STAHEL MAR 85 2/2

UNCLASSIFIED F/G 17/2 NL

END

DATE FILMED

8 85


1·0
2·8
2·5
3·15
2·2
3·5
2·0
4·0
4·5
1·1
1·8
1·25
1·4
1·6

115. Gerhard Merz and Gerhard Pumpe, "Economical Implementation of Dedicated Data Circuits in Public Telecommunications Networks: A Comparison of the Analog and Digital Approaches," _Telecommunication Journal_, October 1984, p. 552.

116. Ibid.

117. "The Push to 'Bypass' Local Telephone Companies," _Business Week_, 27 August 1984, pp. 90-91.

118. Mark D. Maremont, "Did It Make Sense To Break Up AT&T?," _Business Week_, 3 December 1984, p. 86.

119. "The Push to 'Bypass' Local Telephone Companies," _Business Week_, 27 August 1984, p. 90.

120. Ibid., p. 91.

121. Mark D. Maremont, "Did It Make Sense To Break Up AT&T?," _Business Week_, 3 December 1984, p. 86.

122. "Telecommunications: The Global Battle," _Business Week_, 24 October 1983, p. 128.

123. Ibid., p. 127.

124. "U.S. Deregulation Has Common Carriers Slugging It Out," _Business Week_, 24 October 1983, p. 140.

125. "A Scramble to Sell PBX Systems As World Markets Open Up," _Business Week_, 24 October 1983, p. 136.

126. Ibid. p. 138.

127. Ibid., p. 136.

128. "U.S. Deregulation Has Common Carriers Slugging It Out," _Business Week_, 24 October 1983, p. 140.

129. "Communications is Dealing Business a Potent New Hand," _Business Week_, 24 October 1983, p. 132.

130. "Telecommunications: The Global Battle," _Business Week_, 24 October 1983, p. 128.

131. Ibid.

132. Ibid., p. 126.

133. Leonard Lewin, _Telecommunications in the U.S.: Trends and Policies_ (Artech, 1982), p. 25.

134. Graham Langley, "Modern Switching Means Digital Switching," Telephony, 9 July 1984, p. 32.

135. Leonard Lewin, Telecommunications in the U.S.: Trends and Policies (Artech, 1982), p. 25.

136. "U.S. Deregulation Has Common Carriers Slugging It Out," Business Week, 24 October 1983, p. 140.

137. "Sparks Are Flying Among Telephone Switchmakers," Business Week, 24 October 1983, p. 144.

138. John H. Farrell, "The Reality of ISDN," Telephony, 9 July 1984, p. 60.

139. "The Disconnection: AT&T Breakup Benefits are Elusive," Wall Street Journal, 17 December 1984, p. 22.

140. "Former Operating Units Fight AT&T for Business," Wall Street Journal, 17 December 1984, p. 22.

141. "A Scramble To Sell PBX Systems As World Markets Open Up," Business Week, 24 October 1983, p. 136.

142. John Bellamy, Digital Telephony (John Wiley & Sons, 1982), p. 3.

143. Graham Langley, "Modern Switching Means Digital Switching," Telephony, 9 July 1984, p. 38.

144. John Bellamy, Digital Telephony (John Wiley & Sons, 1982), p. 3.

145. L. Ackzell and F. Bigi, "The Transition from Analogue to Digital Telecommunication Networks: The GAS 9 Approach," Telecommunication Journal, September 1984, p. 514.

146. Graham Langley, "Modern Switching Means Digital Switching," Telephony, July 9, 1984, p. 32.

147. "Telecommunications: The Global Battle," Business Week, 24 October 1983, p. 126.

148. Ibid., p. 130.

149. "Sparks Are Flying Among Telephone Switchmakers," Business Week, 24 October 1983, p. 144.

150. Del Myers and Czatdana Inan, "Telecommunications Carriers to Spend $23.634 Billion in 1985," Telephony, 14 January 1985, p. 35.

151. Ibid.

152. Ibid., p. 40.

153. Ibid., p. 35.

154. Allan Gerard, "Business Applications for U.S. Digital Networks," Telephony, 6 February 1984, p. 51.

155. George R. Trimble, Jr., Digital PABX Functions, Features & Applications (Carnegie Press, Inc., 1983), p. 3-6.

156. Allan Gerard, "Business Applications for U.S. Digital Networks," Telephony, 6 February 1984, p. 51.

157. Mark D. Maremont, "Did It Make Sense To Break Up AT&T?," Business Week, 3 December 1984, p. 86.

158. James Connolly, "AT&T 'Orphase' Coming of Age," Computer World, 4 March 1985, Vol. xix, No. 9, p. 8.

159. Mark D. Maremont, "Did It Make Sense To Break Up AT&T?," Business Week, 3 December 1984, p. 86.

160. Allan Gerard, "Business Applications for U.S. Digital Networks," Telephony, 6 February 1984, p. 51.

161. "Boom in Electronic Messages Spurs Demand for Systems Using Fiber-Optic Cable," Wall Street Journal, 9 November 1984, p. 3.

162. Mark D. Maremont, "Did It Make Sense to Break Up AT&T?," Business Week, 3 December 1984, p. 86.

163. Ibid.

164. Allan Gerard, "Business Applications for U.S. Digital Networks," Telephony, 6 February 1984, p. 51.

165. George R. Trimble, Jr., Digital PABX Functions, Features & Applications (Carnegie Press, Inc., 1983), p. 2-13.

166. John A. King, "A Mobile Digital Switching System: Application Note," Telecommunications, November 1984, p. 120.

167. Phillip Robinson, "Gallium Arsenide Chips," Byte, November 1984, p. 23.

168. Ibid.

169. Helmut Lukas, Rick Neumann and Grant Pacey, "Splicing Single Mode Optical Fiber," Telephony, 21 January 1985, p. 45.

170. Gerhard Merz and Gerhard Pumpe, "Economical Implementationof Dedicated Data Circuits in Public Telecommunications Networks: A Comparison of the Analog and Digital Approaches," Telecommunication Journal, Octcber 1984, p. 552.

171. Irwin Lebow, "Secure Voice Systems and Technology," 1979 Data Communications, Sixth Data Communications Symposium, 27-29 November 1979, p. 226.

172. Ibid.

173. Ibid.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93943	2
3.	Professor Jack LaPatra, Code 54Lp Naval Postgraduate School Monterey, California 93943	6
4.	Professor Carl Jones, Code 54Js Naval Postgraduate School Monterey, California 93943	1
5.	Computer Technology Programs, Code 37 Naval Postgraduate School Monterey, California 93943	1
6.	Lt Richard J. Stahel c/o Mr. Alfred Shutts Rt. 10, Lot 4 Asbury Road Murfreesboro, Tenn. 37130	2
7.	Lcdr Jim Richards 11567 Dodge Warren, Michigan 48089	1
8.	Lt Anne Sullivan SMC #2124 Naval Postgraduate School Monterey, California 93943	1

DATE
ILMED
-8